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JOURNAL OF DAIRY SCIENCE

VOLUME XX MAY, 1937 NUMBER 5

THE INFLUENCE OF SUNFLOWER SILAGE UPON MILK PRODUCTION

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INTRODUCTION

Most recommendations for winter feeding of dairy cows have stressed the importance of providing succulence. This recommendation can be followed without difficulty in the corn belt where heavy yields of ensilage are secured from corn. In regions which are not well adapted to raising corn, however, many difficulties are encountered in providing succulence in the winter ration. Such a problem is faced by the farmers of the northern half of Minnesota where, in many cases, the dairy cattle represent the principal source of cash income. Climatic conditions are such that corn returns poor yields of silage, usually of rather poor quality due to its immature condition.

Root crops return large yields per acre, but require a great deal of hand labor and for this reason are not very practical for the larger herds. In addition, the cost of a root cellar is almost as great as that of a silo. The roots are not as convenient to feed, and spoilage is usually great. Sunflowers have been resorted to as a silage crop in this area but in general have not proven popular.

In most of this region, alfalfa is a reasonably dependable crop and gives good yields of hay of fine quality. Other legumes such as alsike and sweet clover are grown with good success in many sections.

In this section of Minnesota, as well as in many other regions of similar climate, silage is provided, not because it is an economical source of nutrients, but because the succulence which it provides is considered necessary. White and Johnson (3) in discussing the literature upon the question of the importance of succulence in the ration state, "The number of experimental trials on record in which a ration of grain and dry roughage has been compared with a ration containing a succulent feed is surprisingly limited. In

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those trials that have been reported from American experiment stations, moreover, it is found that the evidence is not overwhelmingly in favor of a succulent feed so far as milk yield is concerned. It is evident, therefore, that the preponderance of opinion favoring succulent feeds must be due to practical observations, in part, and to the influence of enthusiastic advocates of a system of feeding in which the great forage producing cereal, corn, is the keystone of the roughage elements of the ration."

The last sentence of their statement seems to fit particularly well the case of northern Minnesota, which lies just out of the corn belt. Feeding practices found successful in the corn belt area of southern Minnesota may be recommended in the northern part of the state without proper regard for the difference in climatic and other conditions.

This experiment was undertaken with the view of determining whether sufficiently greater returns are secured with the feeding of a succulent feed in the form of sunflower silage to justify the expense necessary to provide it under northern Minnesota conditions.

PLAN OF EXPERIMENT

This work was carried out at the North Central Experiment Station at Grand Rapids, Minnesota. This station is located in the cut-over region, where climatic and soil conditions are typical of a considerable area of northern Minnesota.

Sunflower silage was used because it is in general use in this region and usually returns considerably greater yields per acre than corn.

The cows were all purebred or high grade Guernseys. Fourteen cows calving in the fall were divided into two groups of seven each, as nearly alike as possible in age, breeding, date of freshening, size, and milking ability as judged by previous records. All of the animals had previously calved at least twice with the exception of two in each group.

The experiment was continued through two entire lactation periods. During the first lactation the cows of Group 2 during the months of stall feeding received three pounds of sunflower silage per 100 pounds of live-weight, together with all of the alfalfa hay they would clean up readily. The cows of Group 1 were given all of the alfalfa hay they could clean up, but received no silage. During the second lactation the two groups were reversed, the cows of Group 1 receiving sunflower silage and alfalfa hay as roughage, while the cows of Group 2 received alfalfa hay but no silage.

All of the cows were given a grain mixture of equal parts of barley, oats, and standard wheat middlings, with one per cent salt and two per cent bone-meal added. The grain was fed in amounts sufficient to maintain milk production and to keep the weight of the cow as nearly constant as possible with due allowance for advancing pregnancy and for normal growth in the immature animals. The protein content of this grain mix-

ture was found adequate for the requirements of the cows of either group, as the alfalfa hay supplied a considerable amount of protein.

During the pasture season no silage was fed to either group. Cows producing less than 10 pounds of milk daily received no grain while on pasture. Cows producing 10 to 15 pounds of milk received 3 pounds of grain daily, and for each 5 pounds of daily milk production above this amount 2 additional pounds of grain were fed. When the pasture became inadequate to supply sufficient bulk, it was supplemented with alfalfa hay in addition to the grain.

Each cow was started on experiment immediately after calving and gotten on full grain feed as soon as was considered practical. The experimental records were started on the sixth day after calving, counting the day of freshening as the first day. The production and feed records were computed for the following 300 days of the lactation period of each cow, and these data were used in comparing the results with and without silage in the ration.

A third group of five cows freshening during the spring and early summer months was included in order to secure observations under conditions of spring freshening. They were handled in a manner similar to the fall freshening cows, all five of them receiving alfalfa and silage during the first lactation, and alfalfa hay but no silage during the second.

Hay samples were taken monthly and preserved until the end of the lactation period when a composite sample was analyzed. A ten pound sample of silage was taken each month, dried to air dry condition, and a composite sample of the air dry material was analyzed at the end of the lactation period. Similar practices were followed for the concentrates used in the grain mixture, samples being taken each time a fresh lot of feed was mixed.

The average digestibility for each feed as given by Henry and Morrison (1) was used in estimating the amount of digestibile nutrients received by the cows.

The sunflowers were grown on the University Experimental Farm at Grand Rapids. The silage was of good quality and free from mold or spoilage.

The alfalfa hay was of excellent quality, largely second cutting, which would have graded U. S. No. 1. Part of it was grown on the University Experimental Farm, while the rest was purchased locally.

Daily milk weights were recorded, and aliquot parts were taken from each milking for individual composite samples which were tested for butterfat by the Babcock method at ten day intervals.

Each cow was weighed on the first, second, and third days of every month and the average computed. They were also weighed in a similar manner when first turned out to pasture. As far as possible, the cows were maintained at uniform weight from month to month, allowing for

average gains with the advance of gestation and for normal growth of the immature animals.

The cows were bred to freshen approximately 12 months after their previous calving. No grain was fed during the dry period except to cows whose weight was below the weight at freshening time of the preceding lactation.

During the pasture season, all of the cattle were kept in the same permanent pasture night and day except at milking time. The grass was largely native blue grass.

All of the cows were turned out for a short time daily during the winter months unless the weather was stormy or extremely cold, but were never left out long enough to become chilled. Drinking cups were available for each cow, and a supply of salt was before them at all times.

They were milked twice daily at regular intervals and were groomed daily, the same attendants caring for them throughout the entire experiment.

In general, feeding and management conditions were made to conform closely to ordinary farm practices on the better dairy farms of this region.

OBSERVATION AND RESULTS

The first of the fall freshening cows calved September 17, 1931, and the last December 6, 1931.

It was found that the cows of both groups consumed much greater quantities of hay than had been expected. When the amount of hay was reduced, the cows would eat the oat straw which was used for bedding.

One cow from Group 1 contracted pneumonia and died during the second year of the experiment. Another cow in the spring freshening group was lost because of a bad case of lump jaw. The remaining cows were in good health and good physical condition and were carried through the entire experiment without any disturbances which might have seriously influenced the final results.

The results of this experiment with the cows freshening in the fall are summarized in Table 1 and Table 2.

It was observed that the production of the cows in both groups was somewhat lower during the second year of the experiment. The only apparent reason for this difference is the fact that pasture was much better during the first year of the experiment. During the summer of 1932, rainfall was adequate for good pasture growth and it was necessary to supplement the pasture only with grain. During the summer of 1933, which fell during the second lactation period of the experiment, rainfall was very inadequate and pasture was poor throughout the season. An average of 970 pounds of alfalfa hay per cow was fed duirng the pasture season of 1933, in addition to the grain supplement. Both groups behaved similarly,

TABLE I

Production and feed consumption during first 300 days of lactation for 13 cows freshening during fall and early winter months. (Succulence provided in the form of Sunflower Silage during winter months.)

COW NO.	AVE. LIVE WEIGHT	CARRIED CALF	ON PASTURE	PRODUCTION			FEED CONSUMED			DRY MATTER CONSUMED	DIGESTIBLE NUTRIENTS RECEIVED	
				Milk	Fat	Fat	Grain	Alfalfa	Silage		Protein	Total
	lbs.	*days*	*days*	*lbs.*	*per cent*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*
Group 1 (1932–1933)												
6	1012	207	128	7664	4.09	313.9	2365	3722	5397	6887	725	4400
17	894	192	75	6350	4.46	283.6	2051	3613	6772	6846	696	4279
12	1023	184	110	6618	4.25	281.7	2167	3105	5775	6233	641	3987
8	986	190	127	5741	5.00	287.4	1985	2228	5180	5115	522	3314
28	812	219	128	7288	4.02	293.5	2221	2624	4218	5453	574	3544
30	879	227	128	5981	4.08	244.1	1857	2489	4443	5060	526	3257
Average	934	203	116	6607	4.30	284.0	2108	2963	5297	5932	614	3797
Group 2 (1931–1932)												
10	1107	215	103	6608	3.97	262.4	2592	3410	5540	6795	698	4877
11	970	162	93	5095	4.53	231.2	1608	4461	5962	6973	682	4195
21	1020	143	91	5364	3.85	206.8	1623	4365	6057	6918	646	4212
19	955	115	77	6452	4.34	270.6	2133	4199	6057	7220	717	4516
2	1155	229	114	9220	3.74	345.2	2829	5347	5377	8735	909	5752
29	788	223	107	4753	4.39	208.9	1216	4053	4507	5898	579	3599
27	844	227	57	6437	3.57	230.3	1684	4118	6459	6828	662	4052
Average	977	188	92	6276	4.00	250.8	1955	4279	5708	7052	699	4458
Group 1 and Group 2												
Total Average	957	195	103	6429	4.14	266.1	2025	3672	5519	6535	660	4153

TABLE II

Production and feed consumption during first 300 days of lactation for 13 cows freshening during fall and early winter months. (No succulent feed provided during winter months.)

COW NO.	AVE. LIVE WEIGHT	CARRIED CALF	ON PASTURE	PRODUCTION			FEED CONSUMED			DRY MATTER CONSUMED	DIGESTIBLE NUTRIENTS RECEIVED	
				Milk	Fat	Fat	Grain	Alfalfa	Silage		Protein	Total
	lbs.	*days*	*days*	*lbs.*	*per cent*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*
Group 1 (1931–1932)												
6	980	71	114	5468	4.09	233.8	1257	6448	.....	7044	765	4241
17	839	114	90	4065	4.84	196.8	886	6188	.....	6466	692	3811
12	996	195	114	5030	4.02	202.6	1091	6195	.....	6651	727	4027
8	972	196	114	4933	4.72	232.9	1458	5163	.....	6062	687	3852
28	850	210	114	7554	3.96	299.4	2391	5722	.....	7415	826	4692
30	956	227	114	5921	3.99	236.4	1818	5561	.....	6765	743	4197
Average	932	169	110	5495	4.22	222.0	1483	5879	.....	6734	740	4137
Group 2 (1932–1933)												
10	1052	240	106	7516	4.09	307.4	2333	4513	.....	6244	730	4101
11	975	202	64	6053	4.78	289.9	1971	5459	.....	6794	790	4271
21	966	228	92	6365	4.04	257.6	2018	4865	.....	6289	732	3987
19	922	235	95	7455	4.42	329.6	2442	5047	.....	6834	797	4394
2	1116	31	54	9757	4.03	393.2	2970	7050	.....	9149	1068	5838
29	814	232	115	5641	4.51	254.4	1646	3677	.....	4862	568	3105
27	779	222	51	6873	3.59	246.8	2009	4682	.....	6109	706	3892
Average	946	199	82	7094	4.19	297.0	2198	5042	.....	6612	770	4227
Group 1 and Group 2												
Average	940	185	95	6356	4.20	267.0	1868	5428	.....	6668	756	4170

however, and when the results of the experiment were summarized it was observed that the average production of all of the cows was almost identical for the lactation period when silage was fed and the lactation period when it was not fed. Total milk production averaged 73 pounds per cow greater when silage was fed, but total butterfat production was 0.9 pound less. Such close agreement between the yields of two successive lactations could hardly be expected, even if treatment were identical, and certainly these results give no indication that the feeding of a succulent feed in the form of sunflower silage influenced the production of the cows in any way. An average of 17 pounds more of digestible nutrients per cow was fed during the lactation period when the ration included no silage and the dry matter consumption was 133 pounds per cow greater. The protein intake was 96 pounds per cow greater due to the fact that alfalfa was fed in greater amounts. The average live weight was 17 pounds greater during the silage feeding period and the cows carried their calves 10 days longer, but they averaged 8 days longer on pasture. It would probably be safe to say that the difference in intake of dry matter and of digestible nutrients is not significant. No difference in health, appetite, or general condition was observed to be associated with silage feeding.

The results with the 4 cows completing the experiment in the spring freshening group are shown in Table 3. In view of the results with the fall freshening groups it seems probable that the greater milk yield during the first lactation was due entirely to the more favorable pasture season rather than to the feeding of silage. This group was probably more seriously affected than the fall freshening groups, since the poor pasture conditions reduced milk flow during the stage of lactation when production is normally at its peak.

DISCUSSION

The results of this experiment give no evidence of any appreciable effect, either favorable or unfavorable, of sunflower silage other than that due to the digestible nutrients which it contains. If this is the case, the question becomes largely a problem of farm management and one which will be determined largely by local conditions. Under the conditions of this experiment, 5519 pounds of silage and 157 pounds of grain apparently served the same purpose as 1756 pounds of alfalfa. Using prevailing local prices for alfalfa hay and for the constituents of the grain mix, the sunflower silage had a cash value at that time of about $2.25 per ton on the basis of the hay which it replaced.

Pond and Crickman (2) give the standard requirement for producing 1 acre of sunflower silage in Northeastern Minnesota as 30.1 man hours and 55.2 horse hours with a yield of 8 tons. An acre of alfalfa was found to require 12.2 man hours and 17.4 horse hours with a yield of 2.5 tons.

TABLE III

Production and feed consumption during first 300 days of lactation for 4 cows freshening during spring and early summer months.

COW NO.	AVE. LIVE WEIGHT	CARRIED CALF	ON PASTURE	PRODUCTION			FEED CONSUMED			DRY MATTER CONSUMED	DIGESTIBLE NUTRIENTS RECEIVED	
				Milk	Fat	Fat	Grain	Alfalfa	Silage		Protein	Total
	lbs.	*days*	*days*	*lbs.*	*per cent*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*
1931–1932 (Silage included in ration)												
4	958	241	103	6928	4.17	289	2206	3681	5692	6773	700	4305
1	1012	193	73	7530	4.27	322	2599	4467	6580	8068	835	5121
3	1090	207	91	8612	4.00	345	2797	4706	6116	8348	857	5212
25	947	219	83	5595	4.37	245	1750	3974	6350	6803	693	4189
Average	1002	860	87	7166	4.19	300.1	2338	4207	6185	7498	771	4707
1932–1933 (No silage in ration)												
4	961	.....	69	6156	4.07	251	1369	4717	.....	5527	613	3416
1	904	182	53	6021	4.13	249	1469	6507	.....	7246	798	4422
3	1115	180	83	8074	3.69	298	2192	6435	.....	7832	873	4895
25	983	210	91	5458	4.17	223	1338	6082	.....	6741	743	4110
Average	991	.....	74	6427	3.97	255.2	1592	5935	.....	6837	757	4211

Using the figures obtained from the analysis of the sunflower silage and alfalfa hay used in our experiment, an acre of alfalfa yielding 2.5 tons would contain 498 pounds of digestible crude protein and 2599 pounds of total digestible nutrients. An acre of sunflowers producing 8 tons of silage would yield 206 pounds of digestible crude protein and 2118 pounds of total digestible nutrients. Requiring less than one half the labor, alfalfa yields a greater quantity of nutrients per acre and more than twice as much protein. Another very important factor is the expense of erecting and maintaining the silo and the expensive equipment required for filling. This is particularly important in the region where this investigation was carried out, since the small cultivated fields are not adapted to use of power equipment and the low cash income often makes purchase of expensive equipment prohibitive. In addition, the fertility of the soil is conserved to much better advantage when alfalfa or other legumes are grown than if sunflowers are grown as a silage crop.

In view of these facts, it seems that the importance of growing legume hay for dairy cows should be stressed in any region where legumes will grow successfully and that the use of silos should not be recommended indiscriminately to dairy farmers in regions which are not well adapted to growing silage crops, merely on the basis of providing a succulent feed.

This conclusion is borne out by recent work at the Connecticut (Storrs) Station by White and Johnson (3). In view of their findings, however, it appears that particular care should be taken to provide a plentiful and ever accessible supply of water for the cows even if a succulent feed is fed, and particularly if dry roughages are used entirely.

This should not be interpreted, however, as minimizing the importance of the silo for preserving to the best advantage the large quantities of roughage produced in the corn belt where the production of silage fits in well with the farming program. Undoubtedly the silo will increase in popularity in regions where weather conditions render field curing of hay very uncertain. This is particularly true in view of recent developments in the preservation of legume crops in the silo, by use of acid or by addition of molasses. There does not appear to be justification, however, for recommending the use of the silo where it will add materially to the cost of producing milk merely because of the physiological need of the cow for "succulence" in her winter ration.

SUMMARY AND CONCLUSIONS

In a group of 13 cows, no advantage in milk production or in health and condition of the cows was found due to inclusion of sunflower silage in the ration containing an abundant supply of legume hay and with water supplied by means of drinking cups. Succulent feed does not appear to be essential for satisfactory production, and it may be inadvisable to attempt

to provide succulent feed when conditions are such that it will add materially to the cost of milk production.

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WRAPPERS FOR PROCESSED CHEESE

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In the preparation of cheese for the processing operation, the rind or outer portion of the cheese unit is removed and its place is taken on the finished product by a so-called wrapper. The purpose of this material is to prevent the access of mold spores to the surface of the cheese, to retard the escape of moisture from the cheese and to serve as a container for a unit mass of cheese which may be sold as such. In addition the wrapper may also serve as an advertising space which if properly used may greatly enhance the appearance of the packaged cheese.

In the selection of a material to be used as a wrapper for processed cheese there are a number of factors that must be given consideration, namely:

1. The wrapper must give a uniformly close seal with the cheese mass so as to eliminate as far as possible air pockets between the wrapper and the cheese.
2. The wrapper must retain the moisture in the cheese so as to prevent drying of the surface and consequent loss of weight.
3. The edges of the wrapper must cling together to prevent access of molds.
4. The wrapper must not impart any off-flavor or color to the cheese.
5. The wrapper should not be affected by the cheese mass in any way.
6. The wrapper should give a pleasing appearance to the cheese unit.
7. The cost of the wrapper should be as low as possible and at the same time the material used should meet all the enumerated requirements.

Before taking up the discussion of the different materials that have been suggested and tried as wrappers for processed cheese, it is desirable to know something of the conditions which exist in the cheese mass. The cheese comes in contact with the wrapper in a molten condition at pasteurizing temperature and the wrapper is then closed about the cheese mass as rapidly as possible. Since there is some evidence that too rapid cooling of the cheese may result in syneresis, it is customary to allow the wrapped unit to cool rather slowly. Thus there is greater opportunity for interaction between the cheese and the wrapper. The cheese mass is somewhat acid in reaction depending upon the type of cheese that is used, and in addition it contains the salts that have been used to facilitate the melting process. While the temperatures involved are relatively low and the total salt con-

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tent of the water-free cheese mass seldom exceeds 10 to 11 per cent, of which 6 to 7 per cent represents the salts present in the cheese before the addition of the emulsifier, there is ample opportunity for reaction between the cheese mass and the wrapper. In connection with the effect of added salts on foil corrosion it may be of interest to mention the work of Csiszar (1) on the use of preservatives in which he points out that such preservatives as common salt, saltpeter and sulfurous acid, when used in amounts sufficient to prevent the spore germination of butyric acid-forming bacteria in the cheese mass, gave a very marked corrosion of the tin-foil wrapper. As a result of the interaction between the foil and the cheese mass, some of the former may be found in the surface layer of the cheese and there may be microscopic and macroscopic evidence of changes having taken place in the wrapper.

Tin foil has been quite universally used as the wrapping material for processed cheese since the beginning of the industry and its cost has been a very important item in the production of the finished product. The cost of the tin foil has served as a stimulus to investigations on the subject of other materials that might be used for processed cheese. There is no record available of all the foils and similar materials that have been tried experimentally, but the cost factor has undoubtedly served to eliminate a number of the metal foils. Certain of the cellulose and rubber composition films have been suggested as wrappers for processed cheese. Their use has not been found very satisfactory since there seems to be a reaction between the wrapper and the cheese mass which gives a very peculiar and rather disagreeable taint to its surface. That this defect is primarily due to heat may be inferred from the fact that when cheese is wrapped in a film of this nature it is usually necessary to use some heat to bring about the adherence of the foil to the cheese. This treatment has resulted in the surface of the cheese acquiring the same bitter taint as has been noted with the processed cheese. When adherence can be brought about by other means, the degree of surface taint has been notably decreased. For this reason the rubber and cellulose composition films have not been used in the processed cheese industry.

In the years that tin foil has been used as a wrapper for processed cheese it has been the subject of a number of investigations in regard to the defects which may appear on or in the foil and the changes which may be imparted to the cheese mass. The average commercial tin foil that was used in reported European investigations contained about 97 per cent tin, about 3 per cent antimony, with a trace of lead and slight amounts of iron and copper. The antimony and lead were added to the tin for technical reasons to increase the strength of the tin. The former is generally mentioned by all investigators as being closely connected with the most common defect that has been noted in the use of tin foil, namely, the darkening of the foil. This

defect ranges from a negligible dulling of the surface of the foil to a decided black coloration which may involve the entire surface of the foil or may be localized to a number of spots. Various investigators do not agree as to the cause of the darkening, some attributing it to an acid reaction of the cheese mass or the use of an acidic emulsifying salt (2), while others feel that insufficient acidity causes the foil to darken (3). In connection with the latter suggested explanation the idea has been advanced that there is a decomposition of the casein with formation of salts of hydrogen sulfide (4). Since lead sulfide is black it has been assumed that this is the substance noted on the tin foil. However, the amount of lead that is present in the tin foil would seem insufficient to account for the intensity of color that is often found.

The explanation for the darkening of the tin foil that seems to be the most satisfactory represents a combination of circumstances and effects; there is a galvanic cell set up between the tin and the antimony (5) with a partial solution of the tin, and the salts formed in combination with oxygen give the blackening of the foil. Analyses of processed cheese samples that have been wrapped in tin foil show an increase in the tin content of the surface layer of the cheese (6). To prevent the solution of the tin, some countries, notably England, require that the surface of the foil in contact with the cheese be coated with a shellac or other material similar to that used for the lacquering of tin cans to prevent interaction between the contents of the can and the container. This remedy has proven satisfactory for reducing the solubility of the tin in the cheese and at the same time the blackening of the foil has been practically eliminated unless the protective film is destroyed.

That oxygen is important in the darkening of the foil is indicated by the fact that the black spots often noted on the foil are found over the air pockets in the surface of the cheese mass. If the foil is removed from the cheese and then replaced there will be a decided increase in the discoloration, which is not apparent if the foil is not brought in contact with the cheese a second time (5).

The salts that are used in the manufacture of processed cheese may accelerate the discoloration of the foil. This is shown in Table 1 in which the samples of cheese were made up with varying amounts of different emulsifiers and the finished product wrapped in a good grade of commercial tin foil. The foils were carefully examined when removed from the cheese samples after less than one month in storage, after 4 months and again after approximately 11 months. The results of these examinations together with the amount of salts used, the pH of the cheese mass, and the total ash content of the cheese on a water-free basis are presented in Table 1.

The results of this investigation indicate that the discoloration of the tin foil is rather closely related to the use of phosphates as the emulsifying

TABLE 1

The effect of various emulsifiers and the reaction of (pH) of the processed cheese on the discoloration of the tin foil

SAMPLE NO.	EMULSIFIER		pH, QUINHYDRONE		PER CENT ASH IN THE DRY MATTER	FOIL DISCOLORATION ON		
	Kind	Per cent	Cheese paste	1–10 Suspension		First exam.	Second exam.	Third exam.
1	Control	– –	5.43	5.86	7.08	– –	– –	– –
2	Sodium citrate	1.0	5.48	5.97	7.38	– –	– –	– –
3	" "	2.0	5.62	6.12	8.07	– –	– –	– –
4	" "	3.0	5.65	6.15	8.68	– –	– –	+ –
5	" "	4.0	5.78	6.30	9.30	– –	– –	+
6	" "	5.0	5.99	6.37	10.08	– –	– –	+
7	Potassium citrate	3.0	5.68	6.15	9.16	– –	– –	+
8	" "	2.5	5.68	6.19	8.99	– –	– –	+
9	" "	2.0	5.61	6.12	8.46	– –	– –	+
10	" "	1.5	5.57	6.03	8.01	– –	– –	+
11	" "	1.0	5.55	5.95	7.73	– –	– –	+ –
12	Tetra-sodium	5.0	6.03	6.49	13.05	+	+ +	+ +
13	Pyro-phosphate	4.0	6.02	6.52	12.71	+	+ +	+ +
14	" "	3.0	5.96	6.40	11.51	+	+	+ +
15	" "	2.0	5.74	6.26	9.90	+	+ +	+ +
16	" "	1.0	5.60	6.12	8.58	– –	+	+
17	Sodium	5.0	5.30	5.80	12.05	– –	+ –	+
18	Meta-phosphate	4.0	5.21	5.65	11.68	+ –	+ –	+
19	" "	3.0	5.20	5.68	10.40	+ –	+	+
20	" "	2.0	5.27	5.72	9.49	– –	+	+
21	" "	1.0	5.36	5.78	8.28	– –	+ –	+ –
22	Mono- and di-sodium	2.0	5.32	5.77	9.24	– –	+ –	+ –
23	Ortho-phosphates	1.0	5.34	5.75	8.25	– –	– –	– –

Explanation of symbols: + + marked discoloration, black spots.
+ general discoloration.
+ – slight, but noticeable discoloration.
– – no discoloration.

agents for processed cheese and to a pH value more alkaline than 5.8 (cheese paste, no dilution) or 6.25 (1 to 10 suspension of cheese in water). This is further confirmed by the results of a comparison of sodium citrate with di-sodium phosphate (ortho) which was made on a number of cheeses processed at various ages, Table 2. All of the cheeses in each series were made from the same original milk. While the amounts of emulsifiers were somewhat larger than commonly employed the additions were calculated to include the water of crystallization in the salts used so that the results are comparable on the basis of the actual salt content of the samples. The samples of the processed cheese were examined after the storage periods indicated. The quality of the original cheese was not exceptional in any way. With the very young and old cheese the samples were so greasy that it is

TABLE 2

The effect of sodium citrate and di-sodium phosphate (ortho) with cheese of varying ages on the discoloration of the tin foil

AGE OF CHEESE	SODIUM CITRATE (2 PER CENT)***			DI-SODIUM PHOSPHATE (2 PER CENT)***		
	pH*	Storage days	Discoloration	pH*	Storage days	Discoloration
1 day	5.93	3	none	6.21	1	none
	.....	41	"	.....	41	"
	.....	124	"	.....	124	"
	.....	183	"	.....	181	slight
3 days	5.97	1	none	6.20	2	none
	.....	40	"	.....	38	"
	.....	124	"	.....	122	"
	.....	181	"	.....	179	yes
8 days	6.13	7	none	6.28	5	none
	.....	35	"	.....	33	"
	.....	119	"	.....	117	yes
	.....	175	"	.....	173	"
8 days**	.....	5	none, 10 days**	.....	5	none
	5.95	33	none	6.19	33	"
	.....	117	"	.....	117	yes
	.....	173	"	.....	173	"
1 mo.	6.11	4	none	6.37	2	none
	.....	95	"	.....	93	yes
	.....	160	"	.....	158	"
	.....	209	"	.....	207	"
2 mo.	6.23	4	none	6.40	2	yes
	.....	33	"	.....	31	"
	.....	63	"	.....	61	"
	.....	129	"	.....	128	"
3 mo.	6.13	1	none	6.36	1	yes
	.....	31	"	.....	31	"
	.....	58	"	.....	58	"
	.....	97	"	.....	97	"
6 mo.	6.25	4	none	6.38	4	slight
	.....	54	"	.....	54	too greasy
	.....	81	"	.....	81	yes
	.....	128	"	.....	128	"
9 mo.	6.26	4	none	6.42	4	none
	.....	38	"	.....	38	yes
	.....	66	"	.....	66	"
	.....	105	"	.....	105	"

* pH determined on a suspension of one part cheese in ten parts of water.

** In these samples the emulsifiers were reversed, that is the cheese that was usually processed with sodium citrate had di-sodium phosphate added and vice versa.

*** Computed on the basis of anhydrous salt.

possible that the fat may have prevented a more pronounced discoloration in the foil. Both Tables 1 and 2 show that the more acid reaction was not

associated with discoloration of the tin foil as often as reactions on the more alkaline side of the limits mentioned. Samples of processed cheese made up with the addition of free acid failed to show discoloration of the foil unless the amount of acid used was such that the body and texture of the resulting processed cheese was affected.

Aluminum foil has been used as a wrapper for processed cheese in an effort to avoid the darkening defect observed with tin foil. In pure form the aluminum foil is rather easily corroded by the action of the cheese salts but the aluminum salts are colorless so that their presence is not readily noted. Certain shellacs and resins have been used as a protective coating on the aluminum foil to prevent corrosion with sastisfactory results. German manufacturers have been active in this field, and as a result of their researches offer aluminum foils with various types of coatings for the prevention of the corrosion of the aluminum foil, and claim to have a coating that facilitates the handling of the foil by the automatic packaging machines used in the processed cheese industry (7). One of the major criticisms of aluminum foil is that it does not behave satisfactorily in the automatic packaging machines. The aluminum foil is somewhat more rigid than tin foil and therefore does not cling to the cheese mass as closely. This may result in air pockets which in turn may be places for mold growth and a loss of moisture from the cheese mass. The latter usually takes place rather slowly so would not cause appreciable loss if the cheese were sold soon after manufacture.

Lead foil has been tried experimentally as a wrapper for processed cheese without success as both the foil and the surface of the cheese were badly discolored after a few days. One investigator has identified lead as being the cause of black spots in the cheese mass (8) but the source of the lead was not the wrapper.

In making a comparison of a number of wrappers, the following materials were used: commercial tin foil, aluminum foil coated with a proprietary resin film, aluminum foil with a dull finish on one side due to the use of another type of protective coating, a rubber composition film and a cellulose film. These wrappers were used with samples of cheese made up with 2 and 3 per cent additions of sodium citrate, di-sodium phosphate (ortho) and tetra-sodium pyrophosphate. Examination of the samples within ten days after making showed that there was no surface taint in the cheese wrapped in tin foil or the aluminum foil with the protective resin film, but all of the other samples showed a noticeable surface taint.

The seal between the foil and the cheese, and the ability of moisture to diffuse through the foil is of commercial importance since a poor seal may result in mold growth and the loss of moisture give a dry surface to the cheese which is not desirable. In this experiment the storage time was not sufficient to permit any extensive mold growths or appreciable loss of

moisture. The average moisture contents of the six samples of cheese in the five types of wrappers are presented in Table 3. From this it is evident that wrapper "E" was somewhat less effective than the others. This

TABLE 3

Average moisture content of processed cheese samples with various types of wrappers*

"A" TIN FOIL	"B" ALUMINUM FOIL RESIN FINISH	"C" ALUMINUM FOIL DULL FINISH	"D" RUBBER COMPOSITION	"E" CELLULOSE COMPOSITION
40.25	40.10	40.35	40.33	39.42

* Each figure represents the average of 6 determinations made 6 to 10 days after processing.

may have been due to diffusion of moisture through the foil and also to the fact that this foil was the most difficult to handle when lining the boxes.

SUMMARY

From the foregoing discussion it is evident that there are a number of factors which play a part in the darkening of the tin foil. The use of phosphate emulsifying salts appears to accelerate the discoloration, especially when the reaction of the cheese-quinhydrone paste is more alkaline than pH 5.8. The results presented in this paper were obtained from investigations on Cheddar cheese, and it is probable that other types of cheese might show different reaction values which are connected with the darkening of the tin foil. It is also probable that there may be some other factors involved, which may be studied at a later date.

It is also evident that the metal foils are still superior to any other type of foils as a wrapper for processed cheese. For general use with all types of cheese tin foil is probably more satisfactory than aluminum foil, but when relative costs are considered there may be types of cheese with which aluminum foil, properly coated to prevent corrosion, may offer distinct advantages.

In conclusion the authors wish to express their thanks to Chas. Pfizer & Co., Inc., for the fellowship under which this investigation has been conducted and also to those who supplied samples of wrappers for this experiment.

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THE MICROBIOLOGICAL FLORA ON THE SURFACE OF LIMBURGER CHEESE* †

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The common practice in limburger cheese factories is to take the cheeses from the salting tables the second or third day after making and pack them together on the shelves of the ripening room. From this time on the cheeses are turned and rubbed with the hand daily, or at short intervals, until they are ready for packing when they are wrapped in parchment and waxed paper and placed in cold storage until ready for distribution.

As the humidity of the ripening room is high, and the temperature is maintained close to 15.5° C. (60° F.) conditions are ideal for the growth of microorganisms. The method of salting leaves a high concentration of salt on the surface of the cheese which tends to inhibit the growth of all but salt tolerant organisms.

A short time after being put on the shelves, the cheeses become slimy and as they are rubbed from day to day the surface becomes smooth and the edges are rounded. Some days later a reddish color appears which spreads over the whole surface as the rubbing continues. This color has been found to vary in different districts of New York State from a reddish-brown to orange.

The bacteria found in the surface smear of limburger and related types of cheese have been studied extensively in Europe. In 1898 Weigmann (1) found *Clostridium licheniforme* and *Paraplectrum foetidum* on the surface of the cheese and considered them as growing in metabiosis, the former preparing the way for the latter by breaking down the lactic acid and making the medium more alkaline. He believed that *Paraplectrum foetidum* was responsible for the typical cheese aroma and flavor. Recently Weigmann (2) stated that a red smear was built up by red bacteria which covered the surface of the cheese and produced anaerobic conditions permitting the growth of *Paraplectridium or Plectridium foetidium*.

In 1899 Laxa (3) working with Bohemian varieties of limburger cheese found *Oidium lactis*, lactic acid bacteria, *Saccharomyces*, and a yellow-pigment producing rod. His conclusions were that *Oospora lactis* consumed the free acid and thus prepared the cheese for the other bacteria. These

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other microorganisms growing together in symbiosis produced the characteristic odor and flavor of the cheese.

Orla Jensen (4), (5) in studies on limburger cheese found *Oospora lactis* in young cheese though he did not consider them as having any part in the ripening. He also found a number of peptonizing bacteria, chiefly *Tetrococcus liquefaciens*, a small spore-forming rod, and yeasts growing together with a rod which he calls *Bacterium casei limburgensis*. From data which he presents he concludes that *Tetrococcus liquefaciens* and *Bacterium casei limburgensis* are responsible for the ripening of the cheese. Orla Jensen (5) states "It is obvious that under normal conditions organism other than those mentioned above participate in the process. Weigmann mentions *Plectridium foetidum* but whether their activity is to be regarded at all desirable may be an open question; it is quite possible that limburger cheese might have a wider market if it contained no products of putrefaction."

Wolff (6) in his investigations on the cause of the orange color in the smear on the surface of cheeses found yellow micrococci and sarcina together with orange and lemon yellow rods. He also found short rods which produced a red-brown pigment and which he designated as *Organismus IX*. Wolff considers this *Organismus IX* as being largely responsible for the red color of the surface smear. In 1910 Wolff (7) at Weigmann's suggestion named this organism *Bacterium linens*.

Filipović (8) made a thorough study of Schwarzenberger, Hagenberger, and Romadour, three limburger types of cheese. In his review he considers certain *Torula* and *Mycoderma* which he found, as having a significant role in preparing the surface of the cheese for the peptonizing rods which later develop in the surface smear. These rods and more especially *Bacterium linens* are responsible for the typical limburger flavor and color. He did not find *Oospora lactis* in the Romadour cheese.

During the early part of 1936 contact slides were made from cheese from each day's make in each of fourteen New York State limburger factories in two different districts. As there was some difference in appearance in the cheeses made in the two districts they are called, for convenience, District 1 and District 2. The contact slides were made by pressing slides against the surface of the cheese until a sufficient amount of the slime adhered to them. They were then allowed to dry and after treating with xylene to extract the fat and with alcohol to harden the smear were later stained and examined under the microscope. By this method it was possible to determine day by day the types and relative numbers of organisms found on these cheeses throughout the time of ripening in the factory. While it should not be assumed that the daily changes shown on a series of cheeses are identically the same as the changes that take place on any individual cheese, still the preparations from a single factory should give

a reasonably accurate picture of the changes that take place on an average cheese from that factory.

The chief difference noted in the cheeses from the two districts was that those from District 1 had a reddish-brown color, while those from District 2 which were softer, more moist, and salted later, developed an orange color. The difference seemed to be related to the lower temperatures in the cellars of District 2 where the cheese ripened much more slowly.

While most of the slides were stained by Hucker's modification of the Gram stain (9) butyl alcohol was used for several series in place of ethyl alcohol as it cleared the background, leaving the organisms more distinct. With this modification of the stain all organisms are gram positive.

RESULTS

Slides from one-day-old cheeses in all series showed budding yeast-like organisms, cocci (mostly in pairs), and rods in about equal numbers (Plates 1 and 2). The yeasts increased rapidly in number until they appeared in

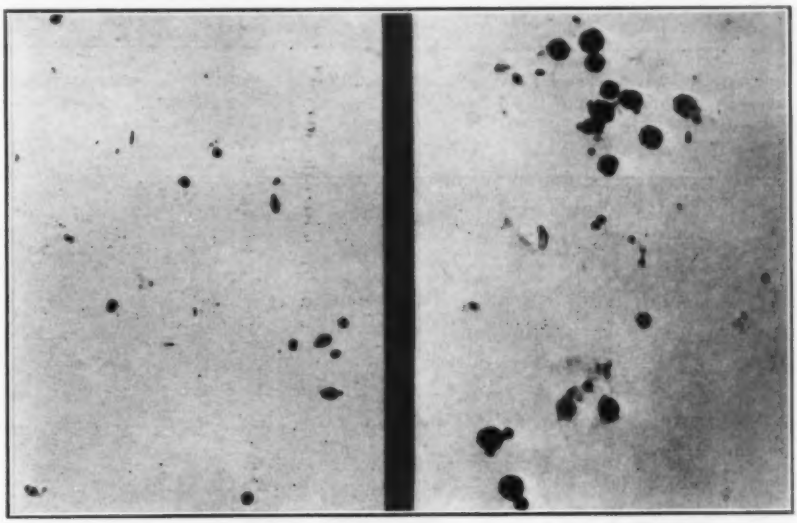

PLATE 1. From cheese one day old showing yeast, rods, and cocci. Magnification 510 ×.

PLATE 2. From cheese one day old. Magnification 1000 ×.

large masses on the cheeses that were two days old (Plates 3 and 4). At the same time the surface of the cheeses became quite slimy. At a later date, and coincident with the appearance of the red color, short slender rods were found to be growing among the yeast cells (Plate 5) and increasing in num-

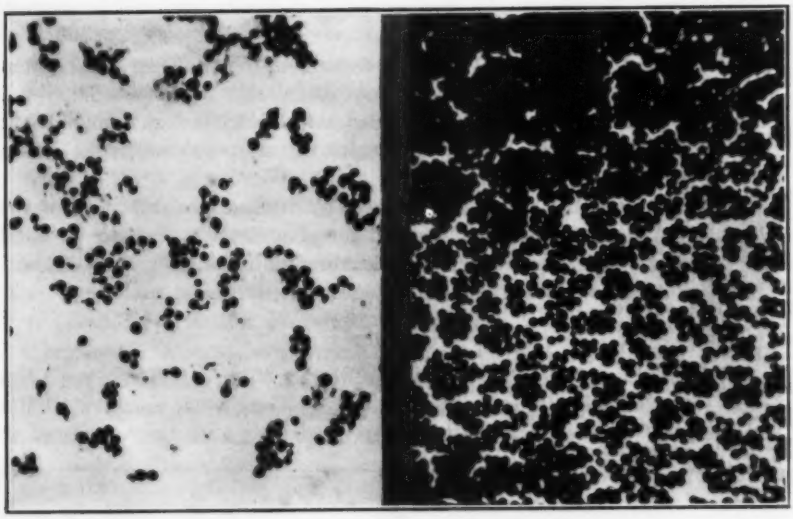

PLATE 3. From cheese two days old showing yeasts making rapid increase. Magnification 510 ×.

PLATE 4. From cheese four days old showing yeast in masses. Magnification 510 ×.

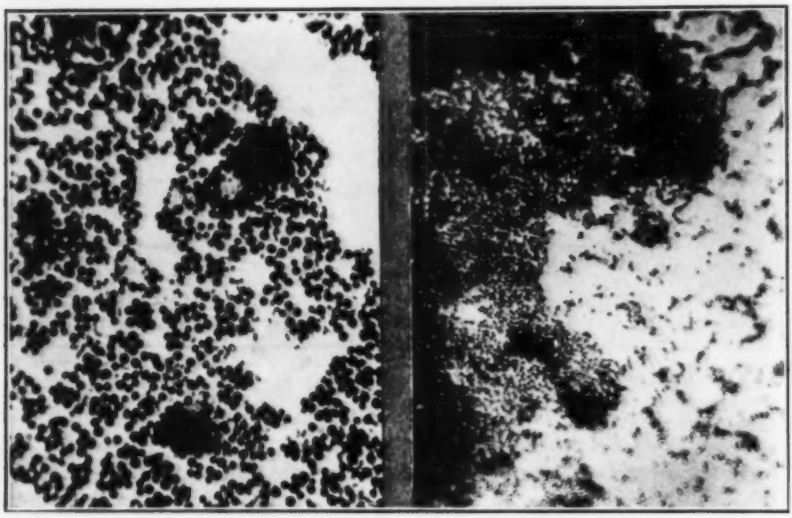

PLATE 5. From cheese six days old showing yeasts in masses and short rods in fairly large numbers. Magnification 510 ×.

PLATE 6. From cheese eight days old showing short rods in large masses. Yeasts were to be found in large numbers though they do not appear in this field. Magnification 510 ×.

ber soon overgrew the yeasts (Plate 6). In time the yeasts tended to die out and the yeast cells were found mostly as poorly stained or distorted forms (Plate 7) while the rods increased until there was a solid mass of bacteria (Plates 6 and 7). The bacteria are found in large numbers up to the time the cheese is consumed.

Oospora were occasionally encountered and in every case where they were found in any number, the cheese showed the peculiar wrinkled appearance associated with the growth of *Oospora lactis*. On the cheese from District 1, very few organisms other than yeast and the short rods were to be found after the first few days, but with the cheeses from District 2 quite a number of larger and thicker rods, and other miscellaneous bacteria were to be noted from time to time; and this more especially during the first week of ripening (Plate 8).

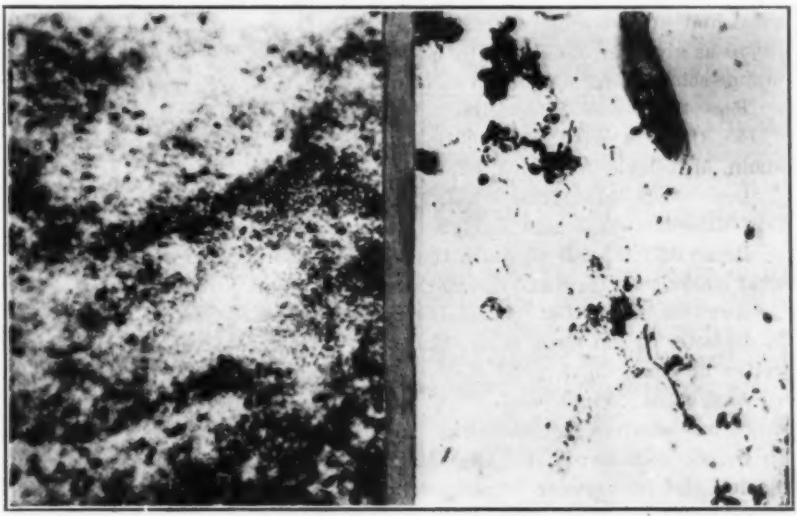

PLATE 7. From cheese seventeen days old showing rods in masses and yeasts starting to break down. Magnification 510×.

PLATE 8. From cheese made in District 2 showing besides yeast, types of bacteria other than the short rods. Magnification 510×.

In District 1, the yeast cells appeared in considerable number on cheeses two to four days old with the majority of cheeses three days old. They reached what seemed to be their maximum number at from four to six days, with an average time of less than five days. On the other hand, though the yeast cells in District 2 made their first appearance at two to three days, they developed more slowly and reached their maximum growth at four to eight days.

The time of the first definite appearance of the rods on the cheese in District 1 showed considerable variation, being from four to eight days, while in District 2 they appeared from the sixth to eighth day. The maximum growth in both districts occurred between the fifth and the tenth day.

The yeast cells started to disappear around the tenth to eighteenth day, but a few were to be found throughout the ripening period.

Cultures of the yeast and of the rod-shaped bacteria have been isolated and a preliminary study has been made of them.

The yeast was found to reproduce by budding, showed no trace of sexuality, spores were not found when grown on gypsum blocks, a pellicle was formed on liquid media from the beginning, and salt was tolerated in concentrations as high as 18 to 20 per cent.

The bacteria are gram positive and tolerate concentrations of salt as high as 18 to 20 per cent. They agree morphologically and in their cultural and physiological characteristics with the description of *Bacterium linens* as given by Wolff and by Steinfatt, the one exception being that no orange-colored ring was observed in milk.

Bacterium linens Weigmann. (Organismus IX, Wolff, Milchwirt. Zent., *5*, 145, 1909; in Wolff, Cent. f. Bakt., II Abt., *28*, 422, 1910, and in Weigmann, Mykologie der Milch, *62*, 220, 1911.

Description taken from Wolff, Milchwirt. Zent., *5*, 145, 1909, and Steinfatt, Milchwirt. Forsch., *9*, 7, 1929.

Rods: 0.6×0.8–1.0 micron without spores, non-motile (Wolff) are somewhat irregular in form and size when grown in liquid media (Steinfatt).

Agar colonies: At 30° C. small colonies are formed and are about 1 mm. in diameter in ten days, shiny, brownish, translucent droplets. Brownish yellow on cheese agar.

Agar slant: At 20° and 30° C. growth good though slow, translucent, shiny, red-brown or reddish-yellow.

Gelatin colonies: At 18° C. punctiform at first and in about twelve days about 1 mm. in diameter. Colony compact, shiny, circular, brownish-yellow to red-brown in color. The gelatin is liquefied.

Broth: The broth becomes cloudy in time.

Milk: At 20° and 30° C. little or no change to be observed after ten days. An orange-colored ring is produced around the wall of the tube, more pronounced at room temperature than 30° C. A reddish-yellow sediment is found at the bottom. The reaction is alkaline.

Potato: After 2 days scanty shiny orange growth in the form of droplets. The potato is mouse-gray in color.

No acid from glucose, lactose, saccharose, galactose, glycerin, mannite, arabinose, raffinose, dextrin and salicin (Steinfatt).

Aerobic.

Temperature relations: Maximum 37° C., optimum 25° C., minimum 9° C.

Distinguishing characters: Produces a shiny orange growth on agar.

Source: This organism represents 10 per cent of a large number of cultures isolated by Wolff from Rahmkäse (a ripened cream cheese).

Habitat: Produces the red-brown slime which covers surface-ripened cheese.

DISCUSSION

As the yeasts and short rods appeared almost in pure culture on the surface of the cheeses in many of the factories where the best cheeses were made, it is logical to suppose that only these organisms are necessary for the surface ripening of the type of cheeses made in New York State. Proper salting of the cheeses as early as possible leaves a sufficiently high concentration of salt to exclude all but these salt tolerant organisms. Where salting is delayed as in many factories in District 2 other microorganisms besides yeasts and *Bacterium linens* may become established on the unsalted curd and be found in considerable numbers throughout the ripening period (Plate 8). These other organisms, while apparently not necessary to the proper ripening of the cheese have not been shown to have a detrimental effect as the quality of the cheese was good. The slower development of both the yeasts and the rods in District 2 is explained by the lower ripening temperatures.

Details of the part played by the yeast and *Bacterium linens* in the ripening of the cheeses are beyond the field of this study, and can only be determined by further research. Undoubtedly, however, through their enzymes they have a major part in the breaking down of the cheese mass from the firm rubbery texture of green cheese to the soft buttery consistency of the ripened cheese.

SUMMARY

The microbiological changes on the surface of ripening New York State limburger cheese as found by microscopic examinations show a very definite sequence. Budding yeasts appear in from two to three days and are found in large masses in four to five days. At this stage the surface of the cheese becomes slimy and the organisms in this slime are distributed evenly over the surface by rubbing the cheeses with the hands.

About the sixth or seventh day short slender rods (*Bacterium linens* Weigmann) appear and increase to large numbers about the eighth day when they are evenly distributed over the whole surface. There is little doubt but that these organisms are responsible for the reddish color which appears on the cheese at this time. The slime on the surface then becomes heavier and is about the consistency of soft butter.

From ten to eighteen days the yeast cells tend to decrease in size, become distorted and disappear entirely. Very few yeast cells were to be found on the older cheeses.

Other types of microorganisms, though present from time to time, do not appear to have any important part in the ripening of the limburger cheeses.

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WATER SOLUBLE CARBOHYDRATES IN FORAGE CROPS AND THEIR RELATION TO THE PRODUCTION OF SILAGE

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There are two outstanding classes of forage crops that are extensively grown on New York farms. These may be conveniently designated as non-legumes and legumes. Under certain conditions both of these can be converted into silage. Such crops as corn, millet and sorghum which are in the non-leguminous class have been used as silage crops for many decades. Little difficulty is ever encountered in obtaining a good product from these crops. Attempts to produce silage from such crops as alfalfa, red or alsike clover and soybeans, which are in the leguminous class, have usually resulted in a product that is not palatable. In a majority of cases the product is returned to the land as a fertilizer.

The extensive increase in leguminous forage crop production for animal feed, both in kind and quantity, has prompted requests for methods of preserving these crops. Other weather conditions retard or prevent the process of haymaking. In a large number of instances the cut material spoils or the hay produced from it is of such an inferior quality that animals refuse most of it. In a few cases a certain quantity of a legume crop may be ensiled with a larger quantity of a non-legume and an acceptable silage produced. Often, however, the legume and the non-legume cannot be harvested at the same time. Other difficulties may arise so that other methods than making a mixed silage have to be practiced in handling these crops.

STATEMENT OF PROBLEM

One of the principal reasons for the numerous failures in the making of silage from legumes was presented by Wilson (4) in an article that dealt with the neutralizing power of forage crops for organic and mineral acids. He pointed out that leguminous materials require more organic or mineral acid to reduce their pH one unit than is required by a similar quantity of a non-leguminous material. He reemphasized also that legume forage crops may be deficient in acid-producing carbohaydrates. If the latter were true these two characteristics of the legumes may explain the numerous failures in efforts to produce silage from such highly nitrogenous crops. This paper, therefore, presents analyses of the water-soluble carbohydrates of both legumes and non-legumes and their relation to the production of silage.

Several investigators have suggested that there should be a high ratio between the fermentable carbohydrates and the other materials such as nitrogen before good silage can be expected. Other workers have concluded

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that the content of fermentable carbohydrates is sufficient to produce the proper degree of acidity in the silage from any green crop, barring a few exceptional cases, and that the only other chemical qualification necessary to a succulent silage is the proper moisture content. However, with such information available there are too many failures in silage making. It is hoped that the data presented will give a better understanding of why it is difficult to produce silage from leguminous forage crops.

METHODS

Due to the possible rapid conversion of soluble carbohydrates of plant tissues into starch, it was desirable to collect samples of plants growing in the field and start the determinations as soon thereafter as possible. Accordingly, in making determinations of soluble carbohydrates, the freshly cut material was taken immediately to the laboratory and the analysis started. The plants were chopped and carefully mixed (so that a sample of the chopped material would represent the entire crop.) From this chopped tissue duplicate portions of about 50 grams each were taken. One was placed in a drying oven at 100° C. This was used to determine the moisture in the sample. The other was placed in a 400 ml. beaker and 200 ml. of water added. The beaker was covered and placed in an Arnold steamer for about 15 minutes. After this heating the sample was allowed to stand over night, if possible, otherwise 4 or 5 hours. The liquid was decanted and a 100 ml. aliquot used. A saturated solution of basic lead acetate was added to this aliquot until no more flocculation occurred. The precipitate was removed by filtration and washed with cold water. Sodium oxalate crystals were added to the filtrate and the solution filtered into a 250 ml. volumetric flask. To the solution in this flask was added 25 ml. concentrated HCl and the mixture allowed to stand over night or heated at 68–70° C. for 10 minutes and cooled. This was necessary in order to hydrolyze polysaccharides to reducing sugars. After hydrolysis by either method, a 40 ml. aliquot was placed in a centrifuge tube. The HCl in the aliquot was neutralized with 25% NaOH using methyl red as an indicator. A volume of Fehling's solution, modified according to Schaeffer (2), equal to the volume of the aliquot was added to the liquid in the centrifuge tube. This was mixed in the tube and the latter placed in a bath of boiling water for exactly 10 minutes. The tube was then transferred to a centrifuge and whirled for at least four minutes. This threw the copper precipitate to the bottom and the supernatant liquid was decanted off. Water was added to the tube and the liquid was again whirled. The water was poured off and the precipitate dissolved in about 10 drops of concentrated HNO_3. For purposes of comparison a dark blue color was then developed by adding a 1–5 solution of NH_4OH. The blue colored liquid was made to a definite volume and compared with that of a standard prepared according to

Schaffer. The quantity of copper was then calculated and the quantity of sugar present calculated from the reduced copper.

This method of determining the water-soluble carbohydrates was compared with the alcoholic extraction method of separating the sugars from interfering substances. Eight comparisons were made. Five of these were with legume forage crops and three were with non-legume forage crops. In every instance the alcoholic extraction method gave a lower percentage of reducing sugars. The difference was not large in any comparison and the average difference was less than four-tenths of one per cent.

Calculating the data:—When forage crops are taken for silage purposes they contain a relatively high percentage of water. This ranges usually from 65 to 85 per cent, with a majority being near 80. With such variations it was difficult to make comparisons of the water-soluble carbohydrates. It was advisable to find a common basis for comparison. Since the water-soluble carbohydrates disappear by being converted in the silo into organic acids which remain in solution and preserve the material, a comparison of these carbohydrates at a uniform percentage of moisture seemed feasible. Therefore, in addition to showing the percentage of these carbohydrates in the dry matter or in the freshly cut material they are shown in the tables also on a basis of 80 per cent moisture. This makes it convenient to compare water soluble carbohydrates of one legume with another or with a non-legume.

Effect of Time of Day on Content of Water Soluble Carbohydrates:—It was recognized that in the daytime carbohydrates may be synthesized more rapidly than they are utilized and that these may be transported or disappear somewhat during the night. If this is true samples of growing plants may have a varying content of water-soluble carbohydrates throughout the daytime. This might necessitate a definite time of day for collecting samples if comparative data are to be obtained. In order to see how much difference there might be, samples of alfalfa and of rye were collected at intervals of 2 hours. The first sample was taken at 4:40 A.M., just at sunrise, and the 7th at 4:40 P.M. The entire day was cloudless. The data are presented in Table 1.

The data show that the percentage of water-soluble carbohydrates in alfalfa from early morning to mid-afternoon remains almost constant. If the results are calculated to a uniform moisture content, say 80 per cent, then at 4:40 A.M. the percentage was 2.17 and it never went above 2.27. At 8:40 A.M. it was just above 2 per cent. The results with rye, through showing about 3 times as much water-soluble carbohydrates as was found in alfalfa, are also fairly uniform. At 4:40 A.M. it was 6.66 per cent and never exceeded 7.9 per cent throughout the day. This is a spread of less than 1.25 per cent.

TABLE 1

Effect of time of day on the percentage of water-soluble carbohydrates

July 1, 1935

TIME OF DAY	ALFALFA (*Medicago sativa*)					RYE (*Secale cereale*)				
	PER CENT WATER	Per cent water-soluble carbohydrates calculated on basis of				PER CENT WATER	Per cent water-soluble carbohydrates calculated on basis of			
		Sap	Dry wt.	Fresh cut	80 per cent moisture		Sap	Dry wt.	Fresh cut	80 per cent moisture
A.M. 4:40	73.0	2.38	6.20	1.74	2.17	65.0	8.20	15.23	5.33	6.66
6:40	70.9	2.57	6.26	1.82	2.28	64.8	7.53	13.86	4.88	6.10
8:40	67.1	2.42	4.93	1.62	2.03	60.6	8.53	13.12	5.17	6.45
10:40	58.5	3.06	6.24	2.05	2.24	57.3	9.89	13.26	5.66	7.08
P.M. 12:40	67.4	2.69	5.54	1.81	2.27	60.6	10.43	16.06	6.32	7.90
2:40	67.6	2.58	5.38	1.74	2.18	59.8	10.09	15.01	6.03	7.54
4:40	67.9	2.55	5.39	1.73	2.16	60.2	9.75	14.75	5.87	7.34

It is concluded that the water-soluble carbohydrates of leguminous plant tissue remain rather uniform throughout the day and that they may increase as much as 1.25 per cent from early morning to midday in the non-legumes. It is doubtful whether this variation carries any significance in silage making. However, since this variation may occur, all samples for analysis were collected around midday.

Effect of stage of maturity on the percentage of water-soluble carbohydrates:—Since large quantities of carbohydrates are used in young growing plants it might be suspected that such plants would have a lower percentage of water-soluble carbohydrates than plants actually setting seed. Data bearing ont this suggestion are given in Table 2.

It is evident that the sugar content of the less mature tissue is significantly lower than that of the more mature tissue. This is true in 16 of 17 observations. The only apparent exception is the comparison of orchard grass taken when it was setting seed and when the seed was ripe. It might be suspected in this case that plants bearing ripe seed would contain less soluble carbohydrates than when setting seed.

It is concluded from the data presented in Table 2 that the stage of maturity of the plants which are taken for an analysis of their water-soluble carbohydrates should be carefully noted.

WATER-SOLUBLE CARBOHYDRATES IN FORAGE CROPS

It was desirable in this study of the water-soluble carbohydrates in forage materials to have analyses of tissues of plants that may or may not be grown as farm crops. Such analyses lend perspective to the results and aid in their interpretation. Accordingly analyses of many plants, representing legumes and non-legumes, some commonly regarded as weeds and usually found on cultivated lands, were made. Since the stage of maturity of the plants influences the quantity of soluble carbohydrates, plant tissue was collected which was sufficiently mature that it might be used for silage making. For convenience of presentation that data are divided into two groups.

Water-soluble carbohydrates in non-legumes:—It will be noted in Table 3 that the date on which the plant tissue was taken is given. This together with the percentage of moisture and the remarks concerning the stage of maturity of the plant gives a fair idea of the succulence or maturity of the material.

Table 3 reveals that numerous non-legumes such as barley, brome grass, corn, crested wheat grass, hard fescue, Italian rye grass, Kentucky blue grass, perennial rye grass, quack grass, rye, sorghum, sudan grass, timothy, and wheat possess a higher water-soluble carbohydrate content than the remaining plants listed in the table. If the quantity of these carbohydrates is expressed as percentage of water in the forage material, this being cal-

TABLE 2

Effect of stage of maturity on the percentage of water-soluble carbohydrates

PLANT TISSUE	STATE OF GROWTH	PER CENT WATER	PERCENTAGE WATER-SOLUBLE CARBOHYDRATES CALCULATED ON BASIS OF			
			Sap	Dry weight	Fresh cut	80 per cent moisture
Alfalfa (*Medicago sativa*)	Before bloom	75.2	1.02	3.10	0.77	0.96
	Beginning to bloom	74.5	1.46	4.26	1.09	1.35
Artichoke (*Helianthus tuberosus*)	Three feet tall	89.5	0.26	2.25	0.24	0.29
	Six feet tall	80.93	2.82	11.93	2.28	2.85
Barley (*Hordeum vulgare*)	Heads just showing	80.7	1.92	7.99	1.54	1.94
	In head	78.7	3.10	11.06	2.42	3.05
Canada blue (*Poa compressa*)	Late flower	66.8	3.03	6.07	2.03	2.53
	Early seed	65.2	3.17	5.94	2.07	2.58
Clover, red (*Trifolium pratense*)	In bloom	75.9	1.81	5.72	1.38	1.72
	Beginning to seed	76.2	3.10	9.92	2.36	2.95
Corn (*Zea mays*)	3 to 4 feet tall	85.4	2.08	12.70	1.77	2.22
	In milk stage	77.64	5.85	20.25	4.54	5.68
Lotus (*Lotus corniculata*)	In bloom	83.4	0.54	2.71	0.45	0.56
	Setting seed	77.5	2.37	8.16	1.83	2.30
Grass pea (*Lathyrus sativus*)	Before bloom	84.3	0.43	2.29	0.36	0.45
	Setting seed	76.1	1.41	4.49	1.07	1.33
Millet (*Chaetochloa italica* var.)	Heads appearing	84.6	0.36	1.99	0.31	0.38
	In seed	70.4	1.99	4.75	1.15	1.75
Orchard grass (*Dactylis glomerata*)	Setting seed	70.0	2.91	6.00	2.04	2.55
	Seed ripe	75.0	1.66	4.98	1.24	1.56

TABLE 2.—*Continued*

Effect of stage of maturity on the percentage of water-soluble carbohydrates

PLANT TISSUE	STATE OF GROWTH	PER CENT WATER	PERCENTAGE WATER-SOLUBLE CARBOHYDRATES CALCULATED ON BASIS OF			
			Sap	Dry weight	Fresh cut	80 per cent moisture
Peas (*Pisum sativum*)	Before blooming	83.9	0.72	3.75	0.60	0.75
	In full bloom	82.7	1.98	9.46	1.64	1.70
Perennial rye grass (*Loleum perenne*)	In bloom	76.6	3.12	10.21	2.39	2.99
	1 week later	65.1	4.69	8.15	3.05	3.82
Rye (*Secale cereale*)	Blooming	74.5	2.07	6.04	1.54	1.93
	Seed in dough	58.8	9.26	13.21	5.44	6.81
Sainfoin (*Onobrychis viciaefolia*)	In bloom	81.9	1.28	5.80	1.05	1.31
	In seed	71.3	2.80	6.96	1.99	2.49
Sheep's fescue (*Festuca ovina*)	After blooming	78.2	3.03	10.87	2.36	2.96
	1 week later	54.9	7.18	8.74	3.95	4.93
Soybean (*Soja max*)	Pods formed	78.2	0.59	2.13	0.46	0.58
	Pods mature	71.0	2.11	5.16	1.49	1.87
Sunflower (*Helianthus annuus*)	2 feet high	87.5	0.68	4.76	0.59	0.74
	Blooming	82.8	2.29	11.03	1.87	2.37
Timothy (*Phaleum pratense*)	Heading	75.1	2.10	6.34	1.58	1.97
	Blooming	71.7	3.13	7.93	2.24	2.80
Vetch (Kidney) (*Anthyllis vulneraria*)	Early bloom	81.8	1.17	5.23	0.96	1.20
	In full bloom	71.1	1.93	4.74	1.37	1.71
Wheat (*Triticum vulgare*)	At bloom time	76.8	4.70	15.50	3.61	4.51
	Seed well formed	62.3	7.82	12.92	4.87	6.09

TABLE 3

Percentage of water-soluble carbohydrates in non-leguminous forage crops

PLANT TISSUE	DATE	PER CENT WATER	PER CENT WATER-SOLUBLE CARBOHYDRATES CALCULATED ON BASIS OF				REMARKS
			Sap	Dry matter	Fresh cut	80 per cent moisture	
Artichoke (*Helianthus tuberosus*)	8/26	80.9	2.82	11.93	2.28	2.85	No bloom, 6 feet tall
Barley (*Hordeum vulgaris*)	7/11	78.7	3.10	11.06	2.42	3.05	Heading
Bent grass (*Agrostus tinuis*)	6/21	78.3	0.95	3.45	6.75	0.92	Before blooming
Brome grass (*Bromus inermis*)	6/21	69.3	3.81	8.60	2.64	3.30	Heading; no pollen
Barnyard grass (*Panicum Crus-galli*)	8/5	83.8	1.44	7.43	1.21	1.51	Seed already formed
Buckwheat (*Fagopyrum esculentum*)	8/5	86.6	0.95	6.16	0.83	1.03	In bloom
Broom corn (*Sorghum vulgare* var.)	8/26	69.0	3.56	5.61	2.46	3.07	Pollen present
Brotex (*Lavatera* spp.)	8/26	80.6	1.99	8.94	1.63	2.00	Before blooming
Canada blue grass (*Poa compressa*)	6/25	65.2	3.17	5.94	2.07	2.58	Early seed stage
Canada thistle (*Circium arvense*)	7/6	82.0	0.58	2.65	0.48	0.59	About to bloom
Chick weed (*Stellaria media*)	7/6	85.1	0.17	0.97	0.14	1.81	In bloom and seed
Chicory (*Cichorium intybus*)	7/6	63.6	0.86	1.50	0.55	0.68	In full bloom
Corn: agr. sel. (*Zea mays*)	8/26	77.6	5.85	20.25	4.54	5.67	In milk stage
sweet (*Zea mays* var.)	8/26	81.7	6.39	28.60	5.23	6.52	Ears ready for market
Creeping red fescue (*Festuca* spp.)	6/28	75.0	1.66	4.98	1.24	1.56	In bloom
Chess (*Bromus secalinus*)	6/21	72.3	4.36	11.37	3.15	3.94	Full heads, no pollen
Crested wheat grass (*Agropyron cristatum*)	6/21	66.5	3.89	7.73	2.59	3.23	Beginning to head
Dandelion (*Taraxacum officinale*)	7/6	80.6	1.03	4.69	0.91	1.04	After seeding, second growth
Daisy (*Chrysanthemum leucanthemum*)	6/24	83.9	2.12	11.05	1.78	2.22	Full bloom
Fescue (*Festuca rubra* var. *arenaria*)	6/28	54.9	7.18	8.74	3.95	4.93	Setting seed
Flax (*Linum usitatissium*)	7/19	78.7	1.12	4.14	0.88	1.10	Beginning to bloom
Hard fescue (*Festuca duruscula*)	6/28	62.2	4.67	7.68	2.96	3.63	In seed
Hemp (*Cannabis sativa*)	7/19	79.6	1.58	6.16	1.26	1.57	About 3 feet high
Italian rye grass (*Lolium Italicum*)	6/28	62.9	7.22	12.24	4.54	5.68	Beginning to seed
Kentucky blue grass (*Poa pratensis*)	6/14	55.6	4.62	5.79	2.57	3.21	In seed
Millet:							
common (*Chaetochloa italica* var.)	8/26	70.45	1.99	4.75	1.15	1.75	In seed
Early Fortune (*Panicum miliaceum* var.)	7/23	87.3	0.425	2.92	0.37	0.46	In head, before blooming

TABLE 3.—*Continued*

Percentage of water-soluble carbohydrates in non-leguminous forage crops

PLANT TISSUE	DATE	PER CENT WATER	PER CENT WATER-SOLUBLE CARBOHYDRATES CALCULATED ON BASIS OF				REMARKS
			Sap	Dry matter	Fresh cut	80 per cent moisture	
Miller:							
German (*Panicum miliaceum*)	8/26	77.1	2.63	8.83	2.02	2.53	Late flowering
Japanese (*Echinochloa frumentacea*)	8/26	69.0	3.45	7.66	2.38	2.97	In seed
Meadow fescue (*Festuca elatior*)	6/21	73.6	2.73	7.61	2.01	2.51	Seed forming
Meadow foxtail (*Alopecurus pratensis*)	6/21	69.4	1.89	4.28	1.31	1.64	Headed but no pollen
Mustard (*Brassica sinapistrum*)	7/6	87.9	0.65	4.72	0.57	0.71	Full bloom
Orchard grass (*Dactylis glomerata*)	6/17	70.0	2.91	6.80	2.04	2.55	Setting seed
Oats (*Avena sativa*)	7/6	76.1	3.12	9.93	2.37	2.97	Heading
Perennial rye grass (*Loleum pirenne*)	6/28	65.1	4.69	8.15	3.05	3.82	In bloom
Plantain (narrow leaf) (*Plantago lanceolata*)	6/17	80.3	2.56	10.40	2.06	2.57	Flowering
Quack grass (*Agropyron repens*)	6/25	66.0	5.40	10.48	3.56	4.45	Blooming
Rye (*Secale cereale*)	6/25	58.8	9.26	13.21	5.44	6.81	Setting seed
Rape (*Brassica campestris*)	7/19	87.8	1.12	8.06	0.98	1.23	
Rough-stalked meadow grass (*Poa trivialis*)	6/28	58.9	2.92	4.18	1.72	2.15	In seed
Sheep's fescue (*Festuca ovina*)	6/21	78.2	3.03	10.87	2.36	2.96	After blooming
Sesame (*Sesame Indicum*)	8/26	84.5	1.36	7.43	1.15	1.44	In bloom
Sorghum vulgare	8/26	81.3	4.08	17.79	3.32	4.15	Pollen present
Sudan grass	8/26	70.4	5.63	13.41	3.97	4.95	Seed-milk stage
Sunflower (*Helianthus annuus*)	8/26	82.8	2.29	11.03	1.89	2.37	Full bloom
Summer foxtail (*Setaria glauca*)	7/19	86.7	0.67	4.37	0.58	0.73	Heads just appearing
Sweet vernal grass (*Anthroxanthum odoratum*)	6/17	60.2	2.74	4.14	1.65	2.06	Late flowering stage
Teosinte (*Euchlaena mexicana*)	8/5	89.6	0.95	7.00	0.72	1.06	
Timothy (*Phleum pratense*)	6/14	70.3	4.71	8.32	2.48	4.14	
" (pasture) (*Phleum pratense* var.)	6/28	78.5	2.99	10.92	2.35	2.93	Prior to blooming
Velvet grass (*Holcus lanatus*)	6/28	67.4	2.22	4.59	1.50	1.87	In seed
Wheat (*Triticum vulgare*)	6/25	62.3	7.82	12.92	4.87	6.09	Setting seed
Yarrow (*Achillea millefiora*)	6/28	85.9	1.09	5.64	0.94	1.17	Blooming

culated for each sample to a uniform moisture basis of 80 per cent, it is clear that all the above-mentioned crops possess more than 3 per cent of water-soluble carbohydrates, the two highest being rye with 6.71 and sweet corn with 6.52 per cent. At least a dozen other non-legumes that are grown or may get into the silo also possess a content of water-soluble carbohydrates of 2 to 3 per cent. In this group are Canada blue grass, oats, plantain, sunflower and timothy. Of lesser interest from the standpoint of silage making but of value in relation to the other data are the water-soluble carbohydrates of many other plants. In this group are such plants as barnyard grass, buckwheat, Canada thistle, chicory, dandelion, flax, hemp, mustard, plantain, rape, velvet grass, and yarrow. These possess less than one per cent of soluble carbohydrates.

Water-soluble carbohydrates in legumes:—The data relating to the water-soluble carbohydrates in legumes are presented in Table 4. For purposes of comparison they are calculated on a basis similar to those shown in Table 3. Only 7 of the 31 legumes examined possessed a water soluble carbohydrate content of 2 per cent or over. Vetch was the highest with 3.34 per cent. The next highest was red clover with 2.95 per cent. Beans, chick pea, lespedeza and lupine possessed less than 1 per cent of these carbohydrates.

PRACTICAL APPLICATION OF THE FINDINGS

It is concluded from the analytical data concerning the water-soluble carbohydrates of forage crops that one of the main reasons why legumes do not ensile satisfactorily is the small quantity of sugar in their tissues. This has been suggested by several workers, notably Reed and Fitch (1) of Kansas, but few if any data comparing legumes and non-legumes have been presented by such workers to substantiate their suggestion. This conclusion is also reached from the data presented in this paper because there is approximately three times as much fermentable sugars in the non-legumes that produce acceptable silages as there is in the legumes that produce inferior silages. This conclusion is also strengthened by the fact that vetch and possibly red clover, which have been the most reliable legumes from which to make silage, have the highest percentages of water soluble carbohydrates of all the legumes analysed.

Influence of the addition of fermentable carbohydrates on the production of silage:—If the failure to produce silage from leguminous tissue is due to a shortage of fermentable carbohydrates it should be possible to supplement them with sugars from other sources and obtain a satisfactory product. Of course this is what Reed and Fitch (1) did but their applications are too expensive. To expand our information on this point, and to place the applications on a practical basis, grass clippings were collected and employed in such a test. The clippings were a mixture of grass with

TABLE 4

Percentage of water-soluble carbohydrates in leguminous forage crops

PLANT TISSUE	DATE	PER CENT WATER	PER CENT WATER-SOLUBLE CARBOHYDRATES CALCULATED ON BASIS OF				REMARKS
			Sap	Dry matter	Fresh weight	80 per cent moisture	
Alfalfa (*Medicago sativa*)	6/14	77.1	1.28	4.32	0.99	1.23	Early silage stage
	6/25	74.5	1.46	4.26	10.9	1.36	Beginning to bloom
Anthylis (*Anthyllis vulneraria*)	7/6	71.1	1.93	4.74	1.37	1.71	In full bloom
Apios (*tuberosa*)	7/23	75.8	1.13	3.54	0.86	1.07	Before blooming
Baptisia (*australis*)	6/28	77.9	2.11	7.44	1.64	2.05	Pods forming
Black locust (*Robinia Pseudo-Acacia*)	7/11	69.8	1.25	2.89	0.87	1.09	
Black medic (*Medicago lupulina*)	6/25	80.2	1.57	6.36	1.25	1.57	Seeds and blossoms
	6/28	75.5	1.37	4.22	1.03	1.29	Seeds and blossoms
Beans (*Phascolus vulgaris*)	8/5	83.4	0.83	4.16	0.69	0.86	Before blooming
Chick pea (*Cicer arietinum*)	8/5	79.9	0.83	3.32	0.67	0.83	Pods formed
Clover, red (*Trifolium pratense*)	6/25	76.2	3.10	9.92	2.36	2.95	Beginning to seed
alsike (*Trifolium hybridum*)	6/25	79.0	1.38	5.19	1.09	1.36	Beginning to seed
hop (*Trifolium agrarium*)	6/17	73.7	2.03	5.70	1.50	1.87	In full bloom
Hungarian (*Trifolium pannonicum*)	7/6	66.9	2.66	5.38	1.77	2.22	In bloom, beginning to seed
Ladino (*Trifolium repens* var. *Ladino*)	6/28	79.4	1.51	5.82	1.20	1.50	In full bloom
Late red (*Trifolium pratense* var.)	6/28	79.7	1.80	7.11	1.44	1.79	Before blooming
Sweet (*Melilotus alba*)	6/21	88.0	1.28	6.23	1.06	1.41	Beginning to bloom
White (*Trifolium repens*)	6/21	81.9	0.99	4.47	0.81	1.01	In full bloom
Yellow sweet (*Melilotus officinalis*)	6/28	75.1	2.27	6.85	1.70	2.13	In full bloom
Cowpea (*Vigna sinensis*)	8/26	79.0	1.74	6.55	1.38	1.72	Beginning to bloom
Dalea (*Alopecuroides*)	8/5	75.6	1.56	4.83	1.18	1.47	Before blooming
Hog peanut (*Amphicarpa monoica*)	7/11	80.5	0.62	2.56	4.99	0.62	
Birdsfoot trefoil (*Lotus corniculata*)	6/25	77.5	2.37	8.16	1.83	2.29	Beginning to set seed
Lathyrus sativus	7/6	76.1	1.41	4.49	1.07	1.34	Beginning to set seed
Lespedeza striata	8/5	74.9	0.53	1.58	0.40	0.50	Blooming
Lupine (*Lupinus perennis*)	7/23	84.2	0.85	4.87	0.72	0.89	After seeds were mature
Peanut (*Arachis hypogeae*)	8/26	75.5	1.41	4.33	1.07	1.33	In bloom
Peas (*Pisum sativum*)	7/16	82.7	1.98	9.46	1.64	1.70	In full bloom
Sainfoin (*Onobrychis vicicafolia*)	6/28	71.3	2.80	6.96	1.99	2.49	In seed, a few flowers
Soybean (*Soja max*)		71.0	2.11	5.16	1.49	1.87	Pods mature
Vetch (*Vici villosa*)	6/6	74.9	3.46	10.32	2.59	3.24	In full bloom

legumes as well as of each separately. They were analyzed for their water-soluble carbohydrates and employed to make silages. The water-soluble carbohydrates of the clippings were supplemented with corn sugar. The relation of the carbohydrates in grass clippings and the influence of supplementing these with corn sugar to the quality of the silage are shown in Table 5.

The influence of the clover in the mixture of grass clippings on the percentage of water-soluble carbohydrates is easily observed. In every instance the mixture of legume and non-legume shows a lower percentage of water-soluble carbohydrates than the non-legume. This situation is also reflected in the acidity of the silage made from these clippings as expressed by their pH. In each instance the pH units were smaller if the silages were made from the non-legumes. When silages were made from the clippings after the addition of corn sugar all mixtures made good silages, while without the sugar only those with the higher percentages of sugar produced silages that appeared satisfactory.

The influence of the added sugar on the reaction and quality of the resulting silage suggests that silage might be made from any legume forage crop provided the proper quantity of an acid-producing substance were added to the forage material. Accordingly soybeans were obtained from the field and chopped finely. This cut material was divided into three portions. One portion was used as a control. To another portion was added corn sugar at the rate of 1.5 per cent of the green weight. To a third portion was added 3 per cent corn sugar. Silage was made from each. The silos were filled on September 22 and were emptied on December 15. The control at this time was of a poor quality. The odor was of such a character that it indicated early stages of putrefaction. Water extracts were dark brown. The silage resulting from the addition of 1.5 per cent corn sugar was acceptable. It possessed a good aroma and no signs of putrefaction were evident. The water extract from this silage was almost clear. The silage resulting from the addition of 3 per cent corn sugar was excellent in every particular. The water extract, however, contained a little more color than the extract from the silage made with the addition of 1.5 per cent corn sugar.

Other legumes have been employed in similar attempts. The experiment with green peas is here described. The chopped vines and pods were placed in silos of 60 pounds, capacity. To the chopped material in one silo was added 1.5 per cent corn sugar, to that in another 3 per cent, and to that in a third 5 per cent. A fourth was filled as a control. The cut material remained in the silos four weeks. The resulting product from each was examined. The best silage was produced from the green peas that received 1.5 per cent corn sugar at the time they were packed in the silo. It possessed the best color, odor and firmness. The silage that was made from

TABLE 5

Relation of water-soluble carbohydrates in grass clippings to quality of silage

PLAT	PER CENT H_2O	PER CENT WATER-SOLUBLE CARBOHYDRATES CALCULATED IN				COMPOSITION OF GRASS	SILAGE			
		Sap	Dry weight	Fresh cut	80 per cent H_2O		pH	Quality	Odor	Remarks
211	82.6	0.89	4.22	0.73	0.92	Kentucky blue grass, wild white clover	5.0	Good	Fair	Too wet
212	76.0	2.34	7.41	1.78	2.22	Kentucky blue grass	4.1	Good	Good	Firm
215	82.9	0.71	3.44	0.59	0.73	Wild white clover	6.6	Fair	Poor	Too wet
226	82.8	0.71	3.42	0.59	0.73	Ayrshire perennial rye grass with white clover	4.8	Fair	Poor	Too wet
227	78.1	1.37	4.89	1.07	1.33	Ayrshire perennial rye grass	4.2	Good	Good	Firm
311	79.7	0.82	3.22	0.65	0.81	Commercial orchard grass, wild white clover	4.9	Fair	Good	Too wet
312	77.1	1.06	3.57	0.82	1.04	Commercial orchard grass	4.5	Good	Good	Too wet
313	78.3	0.76	2.74	0.59	0.74	Stapledon's S.50 Timothy, wild white clover	4.9	Fair	Good	Too wet
319	82.4	0.88	4.12	0.72	0.90	Commercial timothy, wild white clover	4.9	Fair	Good	Too wet
320	76.5	1.76	5.73	1.35	1.67	Commercial timothy	4.2	Good	Good	A little wet
211						Grass with 1½ per cent corn sugar	4.9	Good	Fair	A little wet
211						Grass dried to 73 per cent water	4.9	Good	Fair	Firm
215						Grass with 1½ per cent corn sugar	6.6	Good	Fair	Wet
215						Grass dried to 79 per cent water	5.2	Good	Good	Firm
226						Grass with 1½ per cent corn sugar	4.7	Good	Fair	Wet
226						Grass dried to 74 per cent water	4.9	Good	Fair	Wet
311						Grass with 1½ per cent corn sugar	4.6	Good	Fair	Wet
311						Grass dried to 62 per cent water	4.9	Good	Good	Satisfactory
313						Grass with 1½ per cent corn sugar	4.6	Good	Good	Wet
313						Grass dried to 71 per cent water	4.9	Good	Good	Firm
319						Grass with 1½ per cent corn sugar	4.4	Good	Good	Wet
319						Grass dried to 73 per cent water	4.8	Good	Good	A little wet
320						Grass with 1½ per cent cerelose	4.2	Good	Good	A little wet

the green peas without the addition of sugar was dark, a little soft and of inferior odor, indicating that an undesirable type of fermentation was occurring. The silage resulting from the green peas to which 3 per cent corn sugar was added was also a good product. It was a little bitter to taste but possessed a pleasant odor and a good color. This tendency toward bitterness was pronounced in the silage that was made from the peas to which 5 per cent sugar was added. The color and odor, however, were satisfactory. Apparently nothing was gained by the addition of more than 1.5 per cent sugar to the crop at the time it was packed in the silo.

Satisfactory silage has also been made from numerous other legumes than peas by incorporating with the freshly cut material any readily fermentable carbohydrate that is converted into organic acids. Such substances as glucose, sacchrose, lactose, maltose, and molasses were experimentally employed. These substances that are added for the purpose of increasing the acidity of the silage were applied to forage material in the following percentages: 0.1, 0.3, 0.5, 1, 1.5, 2, 3, and 5. The quality of the resulting silage that was made from the alfalfa to which 1.5 per cent was applied was significantly superior to that produced from alfalfa to which smaller percentages were added. No further increase in the quality of the silage was noticeable with applications larger than 1.5 per cent.

The above information indicates that successful ensiling of legume crops occurred when 1.5 per cent of sugar was added to the crop as it was being packed in the silo. In experiments with alfalfa at Kansas Reed and Fitch (1) added 10 per cent of black strap molasses. Since these experimental silos held only a few pounds it was desirable to test this application of sugar on a larger quantity of material. For this purpose 3-ton silos were available. They were filled with third-cutting alfalfa to which was added, as it went through the silage cutter, about 1.5 per cent corn sugar. The quantity necessary was calculated from the green weight of the crop. A second silo was filled with alfalfa to which was applied 3 per cent corn sugar. These silos were filled on the 4th day of October, 1934.

On the 20th day of November the silo containing alfalfa that was treated when packed with 1.5 per cent corn sugar was opened. Samples were taken for certain tests and the remaining silage fed to cattle. There were no leachings from the silo. From all appearances and tests the silage was unusually good. It possessed an attractive odor, was firm and an acidity of pH 4.5 indicated that sufficient acid had been developed to prevent putrefaction.

The silo that was filled with the alfalfa that was treated with 3 per cent corn sugar was opened after 8 months. The alfalfa had been converted into an excellent silage. An acidity of pH 4.3 indicated that no putrefaction had occurred. The odor was excellent and the silage was also fed to cattle.

Influence of the addition of acids on the production of silage:—It is evident from the results of the experiments just reported that forage crops fail to ferment properly and to produce a high quality silage because they do not contain an ample supply of water-scluble carbohydrates that can be converted into organic acids. Such a condition is made worse by the fact that a larger quantity of acid must be produced in a silo packed with a leguminous crop to insure a satisfactory product than is required in a silo packed with a non-leguminous crop. This is true because leguminous materials have a larger neutralizing power for organic and mineral acids (4) than do the non-leguminous materials. The soluble carbohydrates are converted almost quantitatively under anaerobic conditions in the silo into organic acids. An ample supply of acid-producing substances gives a high quality silage; an insufficient production of organic acids gives an inferior silage.

Since the successful ensiling of forage crops is accompanied by the production of organic acids it should be possible to add acids of one sort or another to freshly cut crops and thus accomplish the same purpose. Success can be obtained by this method. Both organic and mineral acids were employed in such a study. Since the organic acids are weaker than the mineral acids it requires less of the latter to produce the required acidity. Experimentally such acids as hydrochloric, sulphuric, phosphoric, lactic and acetic or combinations of these were employed. They were added either to supplement the acid normally produced by fermentation or in sufficient quantity to reduce the bacterial activity to a minimum. From the experimental standpoint enough of any acid can be used to reduce the pH of the forage material to 4.0. This will reduce bacterial activities to a minimum and produce preservation conditions. If the acid that is added does not produce this condition, fermentation of the water-soluble carbohydrates of the ensiling material will occur and a pleasing odor will be developed simultaneously. From numerous concentrations and combinations that have been tested experimentally in small containers two were selected for trial in 3-ton silos.

Two silos were filled on the 4th day of October with third cutting alfalfa. As the cut material fell into one of the silos equal quantities of 4 normal hydrochloric and sulphur acids were added. The quantity applied was at the rate of 30 liters per ton. This is essentially the formula employed by Vertanen (3) to preserve fresh fodder. When the other silo was being filled there was added to the forage 1.5 per cent corn sugar and 15 liters of a 4 normal hydrochloric acid solution to a ton. Both silos were opened 8 months later and the resulting products examined.

There was no loss of liquid by leaching during this period. The alfalfa that was treated with a mixture of both acids had changed scarcely any. There was a slight odor, indicating that some fermentation had occurred.

The silage was firm and cattle ate it with relish. The acidity as recorded by a potentiometer was pH 4.5. The alfalfa that received the hydrochloric acid and sugar was also an excellent product. The acidity expressed in pH units was 4.5. The odor was *plentiful*, indicating that the hydrochloric acid had produced only partial preservation conditions and that fermentation of the water-soluble carbohydrates to organic acids had carried the acidity on to the preservation point.

DISCUSSION

It was shown previously (4) that more acid is required to change the reaction of leguminous tissues one pH unit than is required by non-leguminous tissue. The data presented in this paper show that the water-soluble carbohydrates, or what may be called the fermentable carbohydrates, of leguminous fodders are considerably lower than those of the non-leguminous fodders. Since the ensiling material is preserved by the production of organic acids that are produced from the fementable carbohydrates, these differences between the two types of forage crops are thought to be the reasons why non-legumes ensile without much difficulty while legumes seldom ensile satisfactorily. When they do ensile properly, it is evidence that they contain an ample supply of fermentable carbohydrates.

This deficiency of the leguminous fodders for silage purposes can be overcome. If the fermentable sugars contained in the legumes are supplemented to the extent of 1.5 per cent of the green weight with any fermentable carbohydrate such as sugars or those materials contained in molasses, a desirable type of fermentation occurs with the result that an acceptable silage is produced. Also, acids, either organic or mineral, may be employed to produce either part or all of the acidity needed for preservation purposes.

Silages made by these methods met every test that is expected of a good silage. The employment of an acid or acids that increase the acidity may preserve certain qualities of the freshly cut material that may be lost when the fodder is allowed to ferment spontaneously. If the hydrochloric or suphuric acid is employed for preservation purposes the resulting silage contains an unusual quantity of acidic radicles. These are much in excess of the nutritional requirements of animals. When the silage is eaten these acidic radicles may reduce the alkaline reserve of the blood.

If phosphoric acid is employed it produces preservation conditions for the fodders, increases the quantity of phosphorus available for animal consumption and results in a higher phosphatic fertilizer for spreading on the land. This makes the phosphoric acid do triple duty and spreads the cost of preserving the silage to more than one farm undertaking. It would seem that phosphoric acid migh be recommended for this purpose because many of our soils and the forage crops grown on them are deficient in this constituent.

In localities where phosphoric acid can be obtained at an economical price its use for silage preservation should be encouraged.

SUMMARY

Leguminous and non-leguminous plants were collected and were analyzed for their water-soluble carbohydrates. Plants of different stages of maturity were collected. They were taken around midday and the analysis started immediately. The tabulated results show the percentages of fermentable carbohydrates in the sap of the plant, in the fresh and dry weight of the plant and in the moisture calculated for each sample to a uniform basis of 80 per cent. Notes that might have some bearing on the production of silage from these crops were made.

The wide difference in the water-soluble carbohydrates of these two types of forage crops suggested that the legumes are deficient in fermentable carbohydrates and thus fail to produce a silage of satisfactory quality.

Acting on this suggestion, silages were made by supplementing the fermentable sugars in the legumes with such substances as corn sugar and molasses. Since these carbohydrates are converted into organic acids both organic and mineral acids were also employed to reduce the pH of the freshly cut material to a point which reduced materially the microbial activity. It was found that silages of superior quality could be made by these methods. In the discussion it was suggested that phosphoric acid might be employed profitably to preserve the fodders; to increase the phosphorus content for animals and to increase the fertilizing value of the farm manure.

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THE OXIDATION OF BUTTERFAT

II. THE COMPOSITION OF THE FAT IN RELATION TO ITS SUSCEPTIBILITY TOWARD OXIDATION*

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A tallowy or oxidized flavor in the milk herds where utmost precautions have been taken to produce clean milk and to protect it from light and metal contamination is often traceable to the milk from one or more cows. Trouble with this off-flavor frequently occurs spasmodically, appearing for a time and then disappearing for no apparent reason. These observations suggest that the difference in the susceptibility of the fat toward oxidation is probably to be found in the composition of the fat.

REVIEW OF LITERATURE

Of 155 cows, representing 5 herds, Guthrie and Brueckner (1) found that 21 per cent gave milk that showed distinctly oxidized flavors, and an additional 10 per cent produced milk which developed a slight oxidized flavor. Except in a few cases, there was no regularity as to which cows would produce milk subject to the development of oxidized flavors.

Chilson (2) reported 25 to 30 per cent of the cows of the Cornell College herd as giving milk during the winter and spring months which developed an oxidized flavor.

Roadhouse and Henderson (3) state that an average of 24.2 per cent of the 349 milk samples entered at the California State Fairs from 1930 to 1934 were criticized as having an oxidized flavor.

The only indication found by Guthrie and Brueckner (1) that there was any relation between the feed of the cow and the production of milk capable of the development of the oxidized flavors was the tendency of most cows that produced milk which acquired these flavors in winter not to produce such milk in summer. These investigators concluded that the dry feeds were not the sole cause of the development of these flavors inasmuch as there was a variation in the intensity of the oxidized flavors developed in the milk from different quarters of the same udder.

Majer (4) claims that the tallowy flavor in the butterfat of milk comes from the feeding of overheated industrial residues and of residues of the sugar industry.

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Kende (5) found that milks of different origins varied in their susceptibility toward tallowy development. This investigator believes that milk contains hitherto unknown organic compounds of complicated composition (reductases) which, depending particularly on the quality of the feed which is given the cow, are contained in the milk in quantities more or less large and which naturally protect the milk from developing oxidized flavors. If these protecting substances are lacking, the milk is extremely sensitive to the action of metals.

Tracy and Ruehe (6) pointed out that tallowiness in market milk is more common in winter than in summer. In a later publication (7) these investigators reported that there was a great variation in the tendency of different milks produced under the same conditions to develop a tallowy flavor which could not be correlated with the percentage of fat present in the milk. They suggest that milks may contain reducing bodies other than bacteria, such as leucocytes, that are a factor in retarding oxidation of the butterfat.

Henderson and Roadhouse (8) report that cows showed differences in the stability of their fat when maintained on the same ration. They found that three cows produced a more stable fat when maintained on an oat hay ration than when alfalfa hay was fed. There was no significant difference in the rate of oxidation of the fat when animals were maintained on the dry and green alfalfa regimes. The samples of fat produced by the cows receiving alfalfa hay contained approximately 36 per cent less carotene than when green alfalfa was fed and oat hay 41 per cent less carotene.

Dahle (9) suggests that feed may have something to do with the tallowy flavor in milk, since it usually disappears in the summer when the cows are on pasture.

Anderson, Hardenbergh and Wilson (24) have made observations which lead them to believe that off-flavored milk from individual cows might be caused by dietary deficiencies.

Guthrie and Brueckner (1) could find no relation between the breed, period of lactation, or age of the cow and the development of the oxidized flavors in the milk.

Lea (10) found that a sample of beef kidney fat with an iodine number of 42.51 was more susceptible to oxidation as measured by peroxide formation and Kreis reaction than a sample of fat with an iodine number of 40.25.

Eckles and Palmer (11) have shown that overfeeding of the cow caused a decrease in the iodine number of the fat, while underfeeding, by which the cow was in a negative nutritional balance, caused an increase in the iodine number.

Henderson and Roadhouse (12) found that the fat from the milk produced from animals drawing upon their body fat by consumption of submaintenance rations showed increases in the percentage of unsaturated fats and increased susceptibility of the fat to oxidation.

Kenneth and Hilditch (13) report an abrupt increase in oleic and linoleic acids when cows go on pasture and a gradual increase in the amount of unsaturated fat as cows age.

Although Hunziker, Mills and Spitzer (14) have shown that feeding cows rations high in linseed oil meal or cottonseed meal will greatly increase the iodine number of the fat, Frazier (15) was unable to determine any difference in the development of a tallowy flavor in the milk of cows fed such rations.

In their work with shortenings for crackers Triebold and Bailey (16) state, "The data indicate that there is no uniform relationship between the iodine number and the keeping qualities (resistance to oxidation) of a shortening. Restricting the comparison to one type of shortening, presumably containing the same unsaturated glycerides, it appears that there is a slight tendency for those samples having the lower iodine number to have the better keeping qualities."

Ruemele (28) has shown that linolenic and linoleic acids oxidize before oleic acid in a reaction mixture containing the three acids. Oleic acid became rancid after absorbing a very small amount of oxygen while the linoleic acid first became rancid after absorbing a considerable amount of oxygen and the linolenic acid did not become rancid on oxidation. This investigator found that a sample of fat containing a large proportion of highly unsaturated acids had to be oxidized to a higher peroxide value and Kreis value in order to develop a rancid flavor than if the fat contained principally oleic acid. At elevated temperatures the decomposition of the more unsaturated product was very rapid and a much lower peroxide value occurred with a rancid flavor than when oxidized at lower temperatures. The action of heat on the flavor and odor development in methyloleate occurred in a much smaller degree than in the product containing linoleic acid.

EXPERIMENTAL PROCEDURE

In these trials, milk from individual cows of the University herd was secured, separated and churned with due regard to the prevention of metal contamination. The various tests reported in this paper were made on the butter oil after the butter had been melted and filtered.

The stability of the butterfat toward oxidation was measured by an accelerated peroxide test. The apparatus used is shown in Figure 1 and is essentially the same as that devised in the Swift Laboratories (17) except for some adaptations added by the authors (18). The peroxide number was determined according to the method proposed by Wheeler (19). The Wheeler test was carried out by gently rotating for 1 minute a 250 cc. extraction flask containing approximately 5 grams of melted butterfat in 50 cc. of a 1:2 mixture of chloroform-glacial acetic acid to which 1 cc. of saturated potassium iodide (freshly prepared) had been added. Fifty cubic centi-

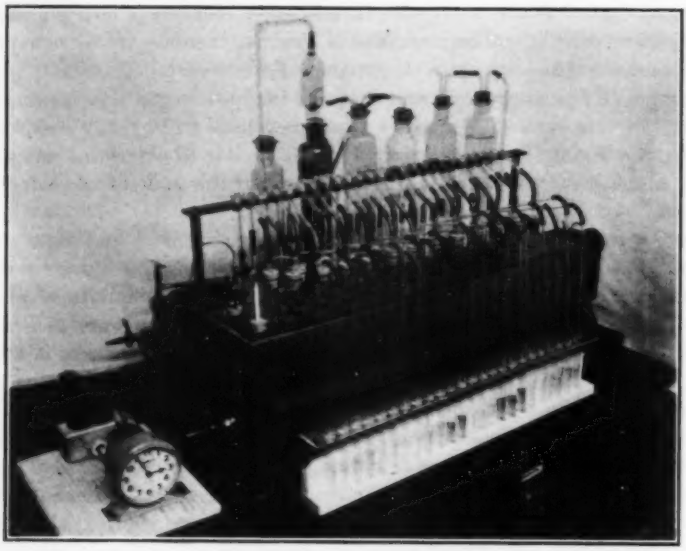

FIG. 1. APPARATUS USED FOR MEASURING THE STABILITY OF BUTTERFAT TOWARD OXIDATION

meters of water were then added and the liberated iodine titrated with standard sodium thiosulphate solution. The results are expressed as "peroxide number" or "peroxide value" which may be defined as the number of millimols of active or peroxide oxygen in combination with one kilogram of oil or fat.

In making stability tests three 20 cc. samples of the same butterfat were placed in the oxidation apparatus in succession at hourly intervals and the approximate end of the induction period determined by absorbing the volatile acids carried over by the aeration in an alkaline solution containing 1 cc. of N/100 sodium hydroxide. The indicator used was methyl red and when it changed from yellow to red in the first of the three tubes, it indicated that the sample of fat was beyond the end of the induction period and had a peroxide number greater than 10. Since the other two samples had been in the apparatus for a shorter period (one and two hours less, respectively) they were still in the induction period or nearing the end. All three samples were removed at this point and analyzed for peroxides. It was found necessary to use great care in cleaning the glassware which came in contact with the fat in making stability tests. Best results were obtained by thoroughly washing the tubes and soaking them in cleaning solution over night, followed by leaching in several changes of distilled water over a period of three to four days.

The stability value of butterfat as used in this paper is defined as the number of hours required to oxidize 20 cc. of butteroil at 100° C. to a peroxide value of 10, when air is bubbled through the fat at the rate of 2.33 cc. per second. The peroxide value of 10 was selected as an arbitrary value indicating the end of the induction period and marking the beginning of the period of rapid peroxide formation (23). A high stability value indicates a good keeping quality fat and vice versa.

The color of the fat was determined by comparison with standard solutions of potassium dichromate and is expressed as the number of millimols of potassium dichromate per liter of solution.

The refractive index of the fat was measured with a Zeiss butyro-refractometer at 40° C.

The iodine numbers were determined according to the Hanus method.

The thiocyanogen-iodine number was determined according to the directions given by Jamieson (20) except that 0.5 gram of fat and 50 cc. of the thiocyanogen solution were used. It was found that in the case of butterfat these larger amounts of fat and thiocyanogen solution gave better results. These findings are in accord with those of Wiley and Gill (21) who recommend 0.4 gram samples and 50 cc. of the thiocyanogen solution.

The percentages of free fatty acids were calculated according to the following formulae:

(X) Per cent linoleic acid = 1.104 (I. No. – SCN No.)

(Y) Per cent oleic acid = 1.112 (2 SCN No. – I. No.)

Per cent saturated acids + unsaponifiable matter = 95.7 – (X + Y)

In view of the findings of Bosworth and Brown (22), in which they report that their attempts to verify the occurrence of ordinary lionleic acid failed but that they found other acids with two double bonds and also highly unsaturated acids of the arachidonic type, these calculations are probably not exact but serve to indicate in a comparative way the amounts of acids with unsaturation greater than oleic acid.

EXPERIMENTAL RESULTS

A. *The Stability of Creamery Butter*

In order to obtain some idea of what could be expected as to the stability value of butterfat, a number of butter samples sent to the University Dairy Department from various creameries for scoring, as well as the butter from the University Creamery, were tested. The stability values as well as the scores of the butter are given in Table 1. As might be expected there was no direct correlation between the score and the stability value, however, it is of interest to note that the lowest scoring sample had the lowest stability value.

TABLE 1

Stability value of various samples of creamery butter

SAMPLE	SCORE	STABILITY VALUE
University creamery	.....	20½
University creamery	.....	19
216	86	8
213	90	21
209	89½	18
207	92½	20½
210	91½	18
212	90½	20
214	90½	19
211	92	14
208	92	14

From these results it appears that fresh creamery butter has a stability value of approximately 20.

B. *Effect of Breed and Individuality of the Cow*

Samples of milk were obtained from a number of cows of the University herd while the cows were all receiving the same winter ration. The ration was quite characteristic of the average Wisconsin dairy herd ration and is given at the bottom of Table 2.

There appears to be a great deal of variation between the individual cows of the same breed and from breed to breed. With the small number of cows tested averages have but little value, but it seems quite definite that in general the milk fat from the Holstein cows on winter rations was more susceptible to oxidation than that from the other breeds. The milk fat from most of the Guernsey cows had an exceptionally high stability value, one as high as 54½.

No opportunity was afforded at the time to check the stability of the fat from day to day as the ration of most of the cows was changed shortly after the first samples were obtained. However, two of these cows, M87 and Lotus, were kept on winter rations and their fat was again tested after about an interval of one month. The fat of M87 showed stability values of 29½ and 15 respectively and that of Lotus 36 and 40½. These values would seem to indicate that the stability of the fat is subject to variations even though the cow is kept on the same ration.

C. *Effect of Feed*

Grass ration.—When the cows were placed on a summer ration where grass replaced the alfalfa hay and the oil meal was omitted from the grain ration, the stability values dropped in all cases except two (see Table 2, cows 67 and Fuschia) and in these two cases the values obtained for the fat on the

TABLE 2

Effect of breed and individuality of cow

BREED	COW	WINTER RATION	SUMMER RATION
		stability value	*stability value*
Holstein	65	42	24
	67	19½	26½
	68	30½	24½
	M 87	29½	.....
	Average	30.4	25
Guernsey	404	51	38
	432	42½	17½
	433	31	24½
	435	41½	25½
	436	54½	22
	Fawn	42	26
	Average	43.7	25.7
Ayrshire	Janice	47½	29½
	Quintilla	52	30
	Lass	18	17½
	Average	39.2	25.6
Brown Swiss	Fuschia	22½	27
	Fidelity	48	27
	Dora	46½	20½
	Average	39.0	24.8
Jersey	Lotus	36	.....

Herd Rations

Winter ration:
- Alfalfa hay
- Corn silage
- Grain:
  - 500 corn and cob
  - 200 oats
  - 100 oil meal
  - 200 bran

Summer ration:
- Grass
- Corn silage—1 feed
- Grain:
  - 700 corn and cob
  - 200 bran
  - 100 oats

winter ration seem to be low as compared to those of the other cows. When the averages of the cows in the various breeds are compared on summer ration the values are so close that it may be concluded that there is no difference.

A. I. V. silage ration.—The fat from another group of cows on A. I. V. silage experiments as well as the check cows was tested for stability. The results are shown in Table 3. Two cows from each lot were later turned out on grass. The fat from three of the A. I. V. silage cows showed excellent keeping qualities while the fat from one cow, M86 (Holstein), stood up for only 6 hours. A later test (about 1 month) while the cow was on the same

TABLE 3

Cows on A. I. V. silage trials

	BREED	MAY	JUNE	
		A. I. V. silage ration	A. I. V. silage and grass	A. I. V. silage ration ; no grass
		stability	*stability*	*stability*
Fair Maid	Brown Swiss	35¾	35½	.....
M86	Holstein	6	.....	22
Lassie	Guernsey	26½	24½	.....
Quintiss	Ayrshire	31½	.....	20

Check Cows

	BREED	WINTER HERD RATION	SUMMER RATION	WINTER HERD RATION
Lass	Ayrshire	18	17½	.....
M87	Holstein	29½	.....	15
Fawn	Guernsey	42	26	.....
Lotus	Jersey	36	.....	40½

ration gave a stability value of 22 for the fat. When these test cows were turned out on grass the stability of their fat was lowered. This is in accord with what was found with the previous group tested.

No hay ration.—The Jersey cow Gem was on a ration which contained no hay during the winter. The fat had a stability of 47, later when the ration was changed to grass the stability value dropped to 38.

Wheat ration.—The Holstein cow Ida was on a ration entirely of the wheat plant. The daily ration was as follows:

Wheat (whole)	8.0 lb.
Wheat middlings	7.0 "
Wheat bran	5.0 "
Limestone	0.6 "
Iodized salt	0.2 "
Wheat straw	15.0 "

The fat had a stability value of 42.

Oat ration.—The Holstein cow M78 was on an oat ration. The daily ration was as follows.

Oats (whole)	9.0 lb.
Oat meal	9.0 "
Special steamed bone meal	0.5 "
Iodized salt	0.2 "
Oat straw	12.0 "

This cow developed scours during which her milk yield declined rapidly. The stability of the fat from this cow was at first 37 and later less than 16.

The data on the various cows used in these trials are given in Table 4.

TABLE 4

Cows used in fat stability tests, May and June, 1935

COW	BREED	AGE	PERIOD IN LACTATION	FLESH CONDITION	DAILY MILK YIELD	WINTER RATION	SUMMER RATION
		Years	*Months*				
65	Holstein	4	2	Thin	55	Herd	Herd
67	"	6	7½	"	31	"	"
68	"	2	8	"	37	"	"
Ida	"	4½	5	Good	16	Wheat ration	Wheat ration; no grass
M86	"	3½	7	Thin	33	A. I. V.	A. I. V.; no grass
M87	"	3½	6	Fair	32	Herd (A. I. V. check)	No grass
M78	"	3½	3	Fair	22	Oat ration	Oat ration
404	Guernsey	7½	4	Fair	30	Herd	Herd
432	"	4	7	Fair	22	"	"
433	"	5	6	Good	24	"	"
435	"	4½	7	Fair	19	"	"
436	"	3½	3	Fair	35	"	"
Lassie	"	4½	8	Good	15	A. I. V.	A. I. V. + grass
Fawn	"	7½	6	Medium	31	Herd (A. I. V. check)	Herd (A. I. V. check)
Gem	Jersey	3½	5	Fair	27	No hay ration	+ grass
Lotus	"	4½	6	Good	17	Herd (A. I. V. check)	No grass
Janice	Ayrshire	3	1½	Thin	42	Herd	Herd
Quintilla	"	3½	5½	Good	29	"	"
Lass	"	3½	7	Good	21	Herd (A. I. V. check)	Herd (A. I. V. check)
Quintiss	"	3½	6	Medium	18	A. I. V.	A. I. V.; no grass
Fuschia	Brown Swiss	7	5	Fair	29	Herd	Herd
Fidelity	" "	4	5	Medium	30	"	"
Dora	" "	3½	6½	Medium	31	"	"
Fair Maid	" "	7	6	Good	30	A. I. V.	A. I. V. + grass

D. *The Relation of Various Fat Constants to Butterfat Stability*

For these trials, eight cows were selected, two from each breed—Guernsey, Jersey, Holstein and Brown Swiss. As shown in Table 5, these cows were

TABLE 5

Cows used in fat stability tests, 1936

COW	BREED	AGE	STAGE IN LACTATION PERIOD AT BEGINNING OF TEST	MAY 5, 1936 MILK YIELD
		years	*months*	*pounds*
Dora	Guernsey	5½	2½	24
Chum	Guernsey	4½	2½	24
Lotus	Jersey	5½	2	17
Safety Belle	Jersey	9	2	20
Fuschia	Brown Swiss	9	1½	27
Fidelity	Brown Swiss	4½	1½	31
Bess	Holstein	3½	1½	40
Rosette	Holstein	3	1	32

all in the early stages of their lactation period but differed in their ages. The data on the stability values and fat constants of the butterfat are given in Table 6.

Whether carotene acts as an antioxidant or prooxidant is still a debated question. The view that carotene acts as a prooxidant is taken by Olcovich and Mattill (25) and Greenbank (26), while Monagahn and Schmitt (27) found that carotene greatly inhibited the oxygen uptake of linoleic acid; but after the carotene had been oxidized it slightly accelerated the oxygen uptake of this acid. From the results reported in Table 6 it may be seen that there is no correlation between the carotene content as measured by the color of the butterfat and the stability of the fat toward oxidation.

The iodine and thiocyanogen numbers show that there is a distinct relationship between the unsaturation of the fat and its stability. In general, the greater the unsaturation the less stable is the fat. When the values for the iodine number and thiocyanogen number are plotted against stabilities as shown in Figure 2, two distinct curves result; one for the values obtained when the cows were on winter rations and one when they were receiving green grass. These results show that even though the fat was more unsaturated and less stable when the cows were receiving grass the fat was more stable for the same degree of unsaturation than when the cows were receiving winter rations. The changes brought about by grass were more pronounced in the butterfat from cows where the iodine number had been low and the stability high when on dry feed.

As shown in Figure 3, a very close relationship was found to exist between the iodine number of buttermilk and its refractive index. As the iodine number of the fat increased the refractive index increased. If refractive

TABLE 6

Relation of various fat constants to stability

COW	RATION	STABILITY VALUE	COLOR OF FAT	REFRACTIVE INDEX	IODINE NUMBER	SCN NUMBER	LINOLEIC ACID	OLEIC ACID	SAT. ACIDS
February 29, 1936									
							%	%	%
Chum	I	64	6	1.4528	26.0	24.8	1.33	26.3	68.1
Dora	I	61	6	1.4526	25.9	24.5	1.55	25.7	68.5
Fidelity	I	57½	2	1.4533	28.7	26.7	2.21	27.5	66.0
Lotus	I	57½	5	1.4530	27.2	26.7	0.56	29.2	65.9
Fuschia	I	45	3	1.4531	27.6	24.8	3.10	24.5	68.1
Bess	I	38	2	1.4533	28.1	28.4	.....	.....	.....
Safety Belle	I	32½	5	1.4536	32.2	30.2	2.21	31.4	62.1
Rosette	I	32	3	1.4543	35.5	33.1	2.66	34.2	58.8
April 7, 1936									
Lotus	II	63	5	1.4528	25.4	24.0	1.55	25.2	69.0
Dora	II	49	6	1.4526	27.1	25.4	1.88	26.4	67.4
Safety Belle	II	45	4	1.4530	28.3	27.1	1.33	28.8	65.6
Rosette	II	.....	2	1.4542	34.6	32.2	2.65	33.2	59.9
Fidelity	II	43½	2	1.4531	27.9	26.2	1.88	27.3	66.5
Chum	II	40	6	1.4527	26.1	24.8	1.44	26.2	68.1
Fuschia	II	.....	2	1.4529	29.0	27.6	1.55	29.2	65.0
Bess	II	.....	2	1.4533	30.2	27.2	3.32	27.0	65.4
May 5, 1936									
Chum	III	47½	5	1.4535	29.3	26.4	3.21	26.2	66.3
Safety Belle	III	43	3	1.4532	29.2	26.3	3.21	26.1	66.4
Fuschia	IV	37	1½	1.4536	32.3	28.6	4.09	27.7	63.9
Fidelity	IV	34½	1½	1.4538	33.6	30.2	3.75	29.8	62.2
Lotus	III	33½	6	1.4534	30.2	27.1	3.42	26.8	65.5
Bess	IV	28	1	1.4543	36.3	32.6	4.09	32.2	59.4
Rosette	IV	24½	1½	1.4553	42.3	38.0	4.76	37.6	53.3
Dora	III	.....	6	1.4532	31.6	27.8	4.20	26.7	64.8

TABLE 6—(*Continued*)

COW	RATION	STABILITY VALUE	COLOR OF FAT	REFRACTIVE INDEX	IODINE NUMBER	SCN NUMBER	LINOLEIC ACID	OLEIC ACID	SAT. ACIDS
				May 19, 1936					
Lotus	V	38	7	1.4545	35.5	32.0	3.87	31.7	60.1
Dora	V	37	8	1.4543	35.5	32.4	3.43	32.6	59.7
Safety Belle	V	33½	7	1.4546	38.0	34.7	3.65	35.0	57.1
Chum	V	32½	10	1.4547	37.4	34.8	2.88	35.9	56.9
Fuschia	V	28½	2½	1.4552	42.4	38.2	4.65	37.9	53.2
Fidelity	V	27½	2½	1.4553	41.9	38.3	3.98	38.6	53.1
Bess	V	26½	2	1.4551	39.8	35.4	4.87	34.5	56.3
Rosette	V	25½	2½	1.4561	44.1	41.0	3.43	42.2	50.1

Rations—Mixed hay throughout

I
Corn Silage
5—corn
2—oats
2—bran
1—oil meal

II
Corn Silage
Corn-alfalfa silage
5—corn
3—oats
2—bran

III
Corn-alfalfa A. I. V. Silage

One Feed	One Feed
5—corn	5—corn
3—oats	5—oats
2—bran	

IV
Same as III except molasses silage instead of A. I. V.

V
Cows on grass May 11
Alfalfa mixed hay
Small amount of A. I. V. alfalfa silage
5—corn
5—oats
5—bran

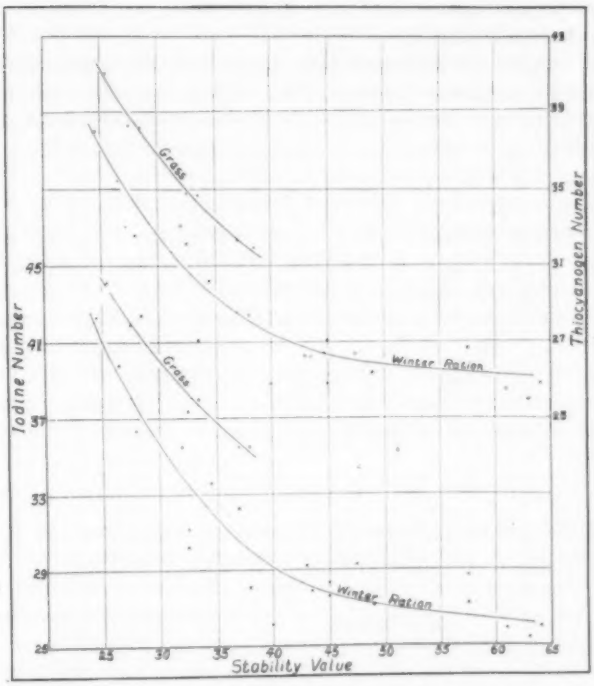

FIG. 2. RELATIONSHIP BETWEEN THE UNSATURATION OF BUTTERFAT AND ITS STABILITY TOWARD OXIDATION.

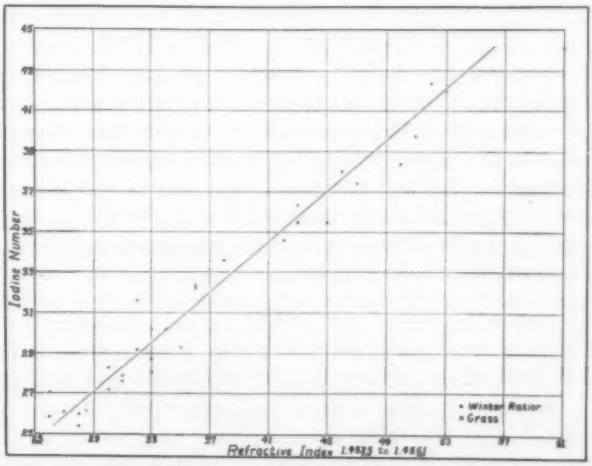

FIG. 3. RELATIONSHIP BETWEEN THE IODINE NUMBER AND REFRACTIVE INDEX OF BUTTERFAT.

indices are plotted against stability values, curves are obtained which are similar to those in Figure 2.

Figure 4 shows the curves obtained by plotting the percentages of oleic and linoleic acids against stability of the various samples of butterfat. In

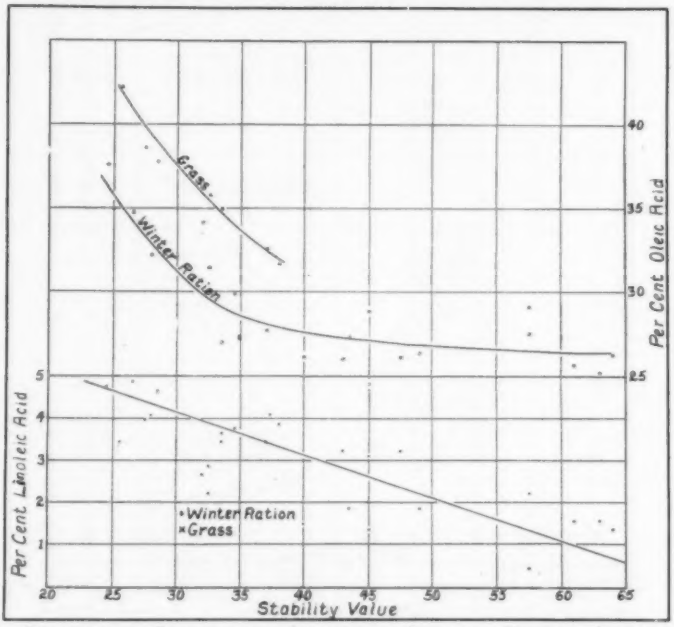

FIG. 4. RELATIONSHIP BETWEEN THE AMOUNTS OF OLEIC AND LINOLEIC ACIDS AND THE STABILITY OF THE BUTTERFAT TOWARD OXIDATION.

the case of oleic acid, two distinct curves are produced similar to those in Figure 2, one for the fat when the cows were on dry feed and the other when the cows received grass. The percentage of linoleic acid appears to be a straight line function of the stability of the fat; decreasing as the stability of the fat increases. The fact that the linoleic acid values for the butterfat from the cows on grass fall on the same curve as the values for the butterfat from the cows on winter rations leads to the conclusion that the percentage of linoleic acid determines the stability.

DISCUSSION

The findings in these trials that the stability of the fat was influenced by its unsaturation is in accord with those of Henderson and Roadhouse (12) who found that the fat from cows on sub-maintenance rations was more unsaturated and more susceptible to oxidation.

In trials covering the spring periods of 1935 and 1936, the authors have shown that when the cows were turned out on grass the fat became more sus-

ceptible to oxidation. These results seem to be contrary to practical experience and scientific observations (1, 9) that the milk from cows on grass is less apt to develop oxidized flavors than when on dry feed. These findings lead the authors to believe that there are protective substances in milk which become more plentiful when the cows are on grass and which prevent the oxidation of the fat even though the separated butteroil is more susceptible to oxidation. The presence of protective substances might explain why Frazier (15) was unable to determine any difference in the development of a tallowy flavor in the milk of cows fed a ration which should have caused the fat to be less saturated and more subject to oxidation.

Although the rations of the cows are included in the data of this paper, no attempt was made in these trials to influence the stability of the fat by changing the ration of the cow.

From the data obtained in these trials it is impossible to attribute the variations in the stability of the milk fat of the various cows or of the same cow at different periods to the age of the cow or the stage in her lactation period.

SUMMARY

There is considerable variation in the stability of the butterfat toward oxidation from different cows and from an individual cow at different times.

The stability of butterfat toward oxidation bears an inverse relation to the unsaturation of the fat.

The fat from cows receiving grass as part of their ration is less saturated and more susceptible to oxidation.

It appears that the amount of linoleic acid rather than the oleic acid governs the stability of butterfat.

The results point to the presence of protecting substances in milk in increased amounts when cows are on grass which prevents the development of oxidized flavors in milk.

There is no relation between the carotene content, as evidenced by the color of the fat, and the stability of the fat toward oxidation.

The refractive index of butterfat varies in direct proportion to the iodine number of the fat.

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THE EFFECT OF HOMOGENIZATION AT DIFFERENT TEMPERATURES ON SOME OF THE PHYSICAL PROPERTIES OF MILK AND CREAM

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The behavior of dairy products homogenized or viscolized at or near the pasteurization temperature has been the subject of many papers and the effects of this process on hot milk and cream and other dairy products are well known. Considerably less attention has been given to the homogenization of milk and cream at temperatures below the melting point of butterfat.

Doan (1, 2, 3) has reported many changes which occur when homogenization is conducted at 100° F. He has shown (4) that the clumping of the fat globules and feathering in coffee is more pronounced when cream is processed at 80° F. than at 180° F. Trout, Halloran and Gould (5) have listed the properties of milk homogenized at 90° F. Rahn (6) studied the distribution and size of fat globules in milk homogenized at 68° F. Dorner and Widmer (7) found that raw milk held 24 hours and homogenized at 41° F. failed to develop a rancid flavor. "Milk drawn only some hours before homogenization became rancid rapidly even if it was cooled to 5° C. (41° F.) and homogenized at this temperature." They concluded that milk processed at this temperature could not be rightfully called homogenized milk, judging from the microscopic appearance.

It is the purpose of this paper to record the observations made on certain properties of milk and cream which were homogenized at various temperatures from 50° to 175° F. and to show the influence of the temperature history of the product prior to its processing.

EXPERIMENTAL

Raw whole milk containing 4.0 per cent fat was thoroughly mixed and divided into 19 portions. These portions were treated in various ways as indicated in Table 1. Two methods of adjusting the milk to the indicated temperature were employed. The first consisted of raising the temperature of the milk, previously held for 18 hours at 40° F. to thoroughly harden the fat, to the homogenization temperature. The heating was done in a careful manner, using a heating medium not over 10° above that of the product. The second consisted of preheating the milk to 145° F. in order to melt the fat and cooling rapidly over a surface cooler to the homogenization temperature. One sample was also processed at 175° F. The samples were pasteurized for 30 minutes at 145° F. immediately after homogenization. Three unhomogenized controls were also included in the series, one being the aged

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raw milk, one being milk pasteurized at 145° F. for 30 minutes and the third flash pasteurized at 175° F. All homogenization was conducted at a pressure of 3000 lbs. per sq. in. using a single stage valve.

Raw 20 per cent cream was treated in the same manner as milk.

After completion of the work described above, the samples were aged over night at 40° F. and then examined as follows:

Milk

Microscopic examination. This included recording the average size of the fat globules and the extent of the fat globule clumping. The milk was diluted with 40 parts of distilled water and a hanging-drop slide prepared. About 10 fields were examined.

Cream volume. The milk was allowed to cream at 40° F. in pint milk bottles and the volume of cream determined in percentage after 24 hours.

Curd tension. Curd tension was determined in duplicate according to the method of Hill (8).

Flavor. The flavor was judged by two experienced judges.

Cream

Microscopic examination. This was the same as for milk except a dilution of 1 part of cream to 200 parts of water was made.

Body. The body or viscosity was measured with a Saybolt Viscosimeter having a tip orifice diameter of 0.082 inches. The number of seconds required to fill a 60 cc. flask at 50° F. was recorded.

Feathering in coffee. Coffee was prepared by mixing 40 grams of freshly ground coffee and 500 cc. distilled water, bringing the mixture to the boiling point. After filtering, the coffee was held in test tubes in a boiling-water bath until ready for use. One cc. of cream was added to 20 cc. of hot coffee and observed for feathering.

Skim layer. The depth of skimmilk layer which formed on the bottom of a pint bottle of cream, after standing over night at 40° F. expressed in inches was termed the skim layer.

Flavor and color. These were judged by two experienced judges.

RESULTS

The observations made on a typical sample of milk, treated as described above, are recorded in Table 1. Table 2 contains the data collected on a typical sample of 20 per cent cream. It will be seen that the temperature of processing had an influence on all of the factors studied. It will also be seen that the effects noted depended in some cases on whether the milk was adjusted to the processing temperature by raising the temperature from 40° F. or by lowering it from 145° F.

Milk (Table 1)

Size of fat globules. Using milk which has been held over night to harden the fat, homogenization at 50, 60 and 70° F. failed to alter the size of the

TABLE 1

The influence of the temperature of homogenization on some of the physical properties of whole (4%) milk. Homogenization was at a pressure of 3000 lbs. per sq. in. using a single stage valve. After homogenizing the milks were pasteurized for 30 minutes at 145° F. and aged 18 hours at 40° F.

HOMOGENIZING TEMPERATURE	TEMPERATURE HISTORY OF MILK	AVERAGE SIZE FAT GLOBULES	FAT GLOBULE CLUMPING	CREAM VOLUME	CURD TENSION	FLAVOR
° F		*microns*		*%*	*gms.*	
50	Held over night at 40°	3–9	–	11	45	Good
	Heated at 145° & cooled	3–9	–	6	45	Good
60	Held over night at 40°	3–9	–	3	40	Good
	Heated to 145° & cooled	3–8	–	3	40	Good
70	Held over night at 40°	3–9	–	3	45	Good
	Heated at 145° & cooled	3–6	–	0	35	Good
80	Held over night at 40°	3–6	–	3	38	Slightly off
	Heated to 145° & cooled	2–5	–	0	30	Good
90	Held over night at 40°	3–6	–	0	30	Rancid
	Heated to 145° & cooled	2–5	–	0	30	Good
100	Held over night at 40°	2–5	+	0	28	Rancid
	Heated to 145° & cooled	1–3	+	0	30	Good
120	Held over night at 40°	1–3	+	0	25	Good
	Heated to 145° & cooled	1–3	+	0	25	Good
145	Heated from 40°	1–3	+	0	25	Good
175	Heated from 40°	1–3	+	0	28	Cooked
Unhomogenized raw milk control		3–9	+++	22	50	Good
Unhomogenized pasteurized (145° F.) control		3–9	+	22	45	Good
Unhomogenized pasteurized (175° F.) control		3–9	–	3	20	Cooked

Key: – = none
+ = slight
++ = definite
+++ = pronounced
++++ = extreme

globules. At 80° there was a slight subdivision and at 100° F. more noticeable subdivision was noted. At 120° and 145° F. the globules were very small. When the milk had been heated to 145° F. to melt the fat very small

globules were obtained when homogenizing temperatures of 145°, 120° and 100° F. were employed. At 90° F. and 80° F. noticeable subdivision was observed, while below these temperatures there was relatively little change in size of the globules.

Fat globule clumping. No clumping of the fat globules was noted under the microscope in any of the homogenized milk samples processed at 90° F. or less. Very slight clumping was noted above 100° F.

Cream volume. Homogenization at temperatures of 90° F. and above eliminated the cream line. It was destroyed at a lower temperature (70° F.) when the milk had been first warmed to 145° F. to melt the fat and then cooled to the homogenizing temperature. Marked reduction in cream volume was noted on all of the homogenized samples and in the unhomogenized control heated to 175° F.

Curd tension. A reduction in curd tension was observed whenever the homogenizing temperature was 90° F. and above. More effective reduction in curd tension was obtained by cooling down to the homogenizing temperature than by warming up. Merely heating to 175° F. also reduced the curd tension.

Flavor. The only off flavor, other than cooked taste caused by high temperature, was the rancid flavor which is generally assumed to be the result of hydrolysis of the fat by the enzyme lipase. Rancidity develops to a much greater extent in raw homogenized milk than in unhomogenized milk because of the greater fat surface exposed to lipolytic action (7). In this experiment the surface of fat exposed was sufficiently increased in the samples homogenized at 80°, 90° and 100° F. to bring about this flavor defect. Apparently heating to 120° F. or higher rendered the enzyme inactive. Temperatures below 80° F. did not provide sufficient surface to bring out the flavor.

Cream (Table 2)

Size of fat globules. In the samples homogenized at the lower temperatures great irregularity in fat globule size was noted. Because of the frequency of globules having a diameter of approximately 15 microns, it seems probable that there was some coalescence of the fat globules. As the temperature of homogenization was raised the tendency to produce small fat globules was increased, depending on the previous temperature history of the sample. A minimum temperature of 90° F. was required to produce noticeable subdivision of the fat globules, when the chilled cream had been warmed from 40° F.; whereas a minimum of 80° F. was sufficient to produce equivalent results when the cream had been preheated to 145° F. Very little clumping was noted in the unhomogenized samples.

Fat globule clumping. Again the previous temperature history of the sample influenced the minimum temperature at which homogenization produced fat globule clumping. Some clumping was observed at 80° F. when

TABLE 2

The influence of the temperature of homogenization on some of the physical properties of 20 per cent cream. Homogenization was at a pressure 3000 lbs. per sq. in. using a single-stage valve. After homogenizing the creams were pasteurized for 30 minutes at 145° F. and then aged 18 hours at 40° F.

HOMOGENIZING TEMPERATURE	TEMPERATURE HISTORY OF MILK	AVERAGE SIZE FAT GLOBULES	FAT GLOBULE CLUMPING	BODY AT 50 ° F.	FEATHERING IN HOT COFFEE	SKIM LAYER IN PT. BOTTLE	FLAVOR	COLOR
° F		*microns*		*Saybolt Secs.*		*inches*		
50	Held over night at 40°	1–15	–	28	–	slight	Good	Light cream
	Heated to 145° & cooled	1–15	+	41	+	slight	Good	Very light cream
60	Held over night at 40°	1–15	–	28	–	slight	Good	Light cream
	Heated to 145° & cooled	1–10	+++	767	+++	1/8	Good	Very light cream
70	Held over night at 40°	1–15	–	31	–	slight	Good	Light cream
	Heated to 145° & cooled	1–8	++++	TT	+++	1/8	Good	Very light cream
80	Held over night at 40°	1–10	+	44	++	slight	Good	Light cream
	Heated to 145° & cooled	2–3	++++	TT	+++	1/8	Good	Very light cream
90	Held over night at 40°	2	++++	TT	+++	1/8	Slightly off	Very light cream
	Heated to 145° & cooled	2–3	++++	TT	+++	1/8	Good	Very light cream
100	Held over night at 40°	2	++++	TT	+++	1/8	Slightly off	Very light cream
	Heated to 145° & cooled	2	++++	TT	+++	1/8	Good	Very light cream
120	Held over night at 40°	2	++++	TT	+++	1/8	Good	Very light cream
	Heated to 145° & cooled	1–2	++++	TT	+++	1/8	Good	Very light cream
145	Heated from 40°	3	++++	350	+++	slight	Good	Very light cream
175	Heated from 40°	2–3	++++	TT	+++	0	Slightly cooked	Very light cream
Unhomogenized raw cream control		3–8	+	59	–	1/8	Good	Cream
Unhomogenized pasteurized (145°) control		3–10	+	31	–	slight	Good	Cream
Unhomogenized pasteurized (175°) control		3–8	+	34	–	slight	Cooked	Cream

Key: – = none + = slight ++ = definite +++ = pronounced ++++ = extreme TT = too thick to measure

the cream had been previously chilled, while cream cooled to 50° F. from 145° F. exhibited some clumping upon homogenization. Above these minimum temperatures homogenization caused extreme clumping.

Body. The temperature of homogenization very markedly influenced the body. This more or less paralleled the fat globule clumping. A slight decrease in viscosity as compared to the unhomogenized control was observed in those samples which had been prepared from chilled cream and homogenized at low temperatures.

Feathering in hot coffee. The temperature of homogenization had a very pronounced effect upon the feathering of the cream in coffee. Feathering was noted in all the homogenized samples except at 50°, 60° and 70° F. when the cream had first been held over night at 40° F. No feathering was noted in any of the controls.

Skim layer. The temperature of homogenization had little effect on the skim layer.

Flavor. Aside from a slight cooked or heated cream flavor in the samples heated to 175° F., there was no pronounced difference in flavor among the samples. A slight off flavor was noted in the samples homogenized raw at 90° and 100° F.; however, unlike the homogenized milk, this flavor was not definitely identified as rancid.

Color. Homogenization at all temperatures had an effect upon the color of the cream as compared to the controls. A decrease in color paralleled the effectiveness of homogenization.

DISCUSSION

Data have been presented to show that homogenization at temperatures ranging from 50° to 175° F. has a marked influence on various properties of milk and cream. For good homogenization, as evidenced by extensive subdivision of the fat globules, it is apparently necessary to have the fat in a more or less liquid state. This condition always exists when the processing temperature is 100° F. or higher. When temperatures below those usually employed were used the method of adjusting the temperature was found to affect the results. From the data presented in this paper it is possible to speculate as to the condition of the butterfat at the various temperatures used. Table 3 summarizes the conclusions drawn in this regard.

An interesting observation made in connection with this research was in the homogenization of cream at 70° F. Two lots of 20 per cent cream at 70° F. were prepared, one lot having been adjusted to this temperature after aging at 40° F., and the other heated to 145° F. and then cooled to 70° F. Various proportions of these two lots of cream were immediately mixed and homogenized at a pressure of 3000 lbs. per square inch. Microscopic examination of these homogenized creams showed both homogenized and unhomogenized fat globules, the amounts of each roughly paralleling the proportion of liquid to solid fat as determined by the source of cream. The extent

TABLE 3

The condition of butterfat in milk and cream at various temperatures ranging from 50° to 175° F. as influenced by the temperature history. The condition of the fat was indicated by the properties of the homogenized product

HOMOGENIZING TEMPERATURE	TEMPERATURE HISTORY OF PRODUCT	
	Aged at 40° F. before homogenization	Heated to 145° F. before homogenization
° *F.*		
50	solid	solid
60	solid	soft
70	solid	soft
80	soft	liquid
90	soft	liquid
100	liquid	liquid
120	liquid	liquid
145	liquid	liquid
175	liquid	liquid

of fat globule clumping, feathering, and the viscosity were governed by the proportion of liquid fat in the homogenized mixture.

SUMMARY

1. Data are presented on several properties of milk and cream as influenced by single-stage homogenization at a pressure of 3000 lbs. per square inch at various temperatures ranging from 50° to 175° F.

2. The butterfat in milk and cream must be liquid or in a relatively soft condition in order to obtain, upon homogenization, changes in the recorded properties.

3. The condition of the butterfat existing in milk and cream immediately after adjustment to temperatures between 60° and 90° F. depends upon the temperature treatment of the product prior to its adjustment to these temperatures.

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American Dairy Science Association Announcements

THIRTY-SECOND ANNUAL MEETING, UNIVERSITY OF NEBRASKA, LINCOLN, NEBRASKA AGRICULTURAL COLLEGE CAMPUS, JUNE 22–25, 1937

GENERAL INFORMATION

Lincoln is a city of 80,000 people, the capital of the State of Nebraska. Within the city or in its environs, are located the University of Nebraska, Nebraska Wesleyan University, and Union College. Morrill Hall, the museum of the University of Nebraska, has the finest collection of fossil elephants in the world and is one of the good museums of natural history in the United States. The Nebraska State Capital is considered by architects one of the most outstanding buildings in America. Lincoln is located on the main line of the Burlington Railway between Chicago and Denver, and on the main line of the Rock Island between Chicago and Kansas points. It is also served by the Union Pacific, Northwestern, and Missouri Pacific. Highway U. S. 6, the cross continental highway, runs through Lincoln and U. S. 77 carries traffic north and south. Main highways from Lincoln lead to the Yellowstone and Rocky Mountain National Parks and to the Black Hills. The lake region of Minnesota can be reached easily by good highways.

HOUSING

Those attending the meetings can obtain accommodations at the hotels of Lincoln. Each member of record last fall will be sent a list of hotels showing the kind of accommodations that can be obtained, for one or for a party. In addition to the hotels, accommodations may be obtained for the men at the Y. M. C. A. and at the Alpha Gamma Rho house. To facilitate the housing, it is requested that reservations be made through Prof. H. P. Davis, Dairy Husbandry Department, University of Nebraska, Lincoln, Nebraska. As soon as the hotel has confirmed the reservation notification will be sent out. The cost of rooms will vary from .75c to $2.50 per day depending upon the accommodations.

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ABSTRACTS OF LITERATURE ON MILK AND MILK PRODUCTS

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JOURNALS

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SPECIAL PUBLICATIONS

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ABSTRACTS OF LITERATURE ON MILK AND MILK PRODUCTS

BACTERIOLOGY

125. New Germicidal Rays Retard Mold Growth. Ice and Refrig. *19*, 1, p. 1, July 1936.

The Westinghouse Lamp Co., Bloomfield, N. J. has announced a new low-wattage gaseous conductor device which produces radiations germicidal to mold spores in the air. Its trade name is Sterilamp. It consists of a slender glass tube containing a small quantity of special gas. Electricity sent through the tubes produces the germicidal rays. Thus far the apparatus has been used only in the process of "tenderizing" meat. The cost of operation is low, and air passing through ducts where the lamps are located reaches a high degree of sterility. The radiations tend to kill houseflies after several minutes' exposure, and fruit-flies, roaches, grain weevils refuse to enter the area of exposure. The article makes no mention of any effect upon human beings. L.C.T.

126. Studies on the Bactericidal Action of Bovine Whole Blood and Serum Towards Brucella Abortus and Brucella Suis. M. R. Irwin, B. A. Beach and F. N. Bell, University of Wisconsin, Madison. J. Inf. Diseases *58*, p. 15, Jan.–Feb. 1936.

Experiments were conducted on cattle that had recovered from infection with *Brucella abortus* and on those that had not been infected in the hope that differences might be found in the bactericidal action of blood or serum from the two groups of animals and that the resistance of an animal to infection might be predicted from a test on the bactericidal action of the blood.

It was found that bovine serum normally contains bactericidins for *Brucella abortus* and is slightly more active in this respect than the corresponding whole blood. There is a difference between animals in bactericidal activity of serum or blood, but each animal showed uniformity in reaction at different times. The animals that had recovered from a previous infection with *Brucella abortus* showed a loss in the bactericidal properties of the blood as compared to that of presumably normal animals.

Bovine whole blood exerted no bactericidal effect on *Brucella suis* and the serum had less effect than on *Brucella abortus*. W.C.F.

127. Comparative Observations on Streptococci from Human Gastro-Intestinal Ulcerations and from Bovine Mastitis. John C. Torrey and Elizabeth Montu, Cornell University Medical College. J. Inf. Diseases *58*, p. 105, Jan.–Feb. 1936.

"A comparative study was made of authentic strains of the Bargen

diplo-streptococcus of ulcerative colitis, of selected enterococci associated with the same disease, of representative strains of Saunders' streptococcus of gastro-duodenal ulcers and of streptococci associated with bovine mastitis."

"Biochemical and serological tests indicated only exceptionally any relationship between the streptococci associated with ulcerative processes in the human gastro-intestinal tract and *Streptococcus mastitidis* of bovine origin. On the other hand, three streptococcal strains from mastitis milk not related culturally or serologically to *Streptococcus mastitidis*, exhibted such relationships to two enterococcus strains from ulcerative colitis and to certain of the Saunders peptic ulcer and carcinoma strains. These and other findings suggest a bovine origin for certan enterococcus-like organisms capable of invading human tissues." W.C.F.

128. Clinical Aspects of an Outbreak of Typhoid Fever. S. W. SMITH. Lancet *231*, p. 1450, Dec., 1936.

In August and September, 1936 an outbreak of typhoid fever occurred in three neighboring communities in Dorset and Hampshire, England. During the course of the epidemic there were 523 reported cases and 41 deaths.

The cause of the epidemic was an infected raw milk supply from one dairy. On August 22nd this milk was pasteurized, and in three weeks the outbreak had ceased.

Since the epidemic was milk-borne, children were the greatest sufferers, the disease being most common among those between the ages of 10 and 35.

The author discusses the symptoms, prognosis, and treatment of the disease. Pure milk is the principal food employed in building up the patient. J.A.T.

BUTTER

129. Testing Cream and Butter for Extraneous Matter. ROBERT P. MYERS, AND RANDALL WHITTAKER, Am. Creamery and Poultry Prod. Rev. *79*, 15, p. 502, Feb. 13, 1935.

For preparation of butter samples for filtration and sediment test the authors advise that either N/20 hydrochloric or sulfuric acid is preferable to 4 per cent borax solution. For filtering, 100 x 100 nainsook cloth from fibers 6/1000 of an inch in diameter was found best. The size cloth considered best is 1.8 square inches or a circle 1½ inches in diameter. No sediment tester now on the market contained all the desirable features such a tester should have. Sediment discs may be mounted wet on cards and filed in envelopes of cellophane or pliofilm or on small squares of glass. P.S.L.

130. A Cream Denaturant. W. F. JENSEN, Am. Creamery and Poultry Prod Rev. *79*, 9, p. 293, Jan. 2, 1935.

In order to color condemned cream, the author recommends the use of

erythrosine, a certified food color, at the rate of one gram for ten gallons of cream. The color is harmless. It costs $17.00 per pound, this amount being sufficient to color 4540 gallons of cream. P.S.L.

Other abstracts of interest are numbers 125, 134, 139, 140, 141, 143, 144, 145, 146, 147, 148, 151, 152, 153, 154, and 155.

CONCENTRATED AND DRY MILK

Abstracts of interest in the concentrated and dry milk industry are numbers 125, 131, 134, 137, 139, 140, 141, 143, 144, 145, 146, 147, 148, 149, 151, 152, 153 and 154.

FOOD VALUE

131. Vitamin G Concentrate. G. C. SUPPLEE, Borden Co., New York City, Am. Creamery and Poultry Produ. Rev. *80*, 10, p. 317, July 10, 1935.

Dr. Supplee's announcement of the production of the first concentrate of vitamin G is important to health authorities interested in the prevention of pellagra. This disease is common to the South, the number of cases in 1932 amounting to 15,643 and deaths 4,134. Principal sources of vitamin G have been yeast and liver. Vitamin G is shown to consist of two components, one identified as lactoflavine, the growth promoting factor, and the other, as yet unnamed, is considered the anti-pellagra factor. The two may be isolated from whey or concentrated whey. Lactoflavine is present in whey to the extent of 3 to 5 parts per million. The presence of vitamin G is determined by ultra violet rays, the product in a dark room showing a brilliant yellow fluorescence, even in minute quantities. To date whey appears to be the cheapest source of the vitamin. P.S.L.

ICE CREAM

132. The Association's Year. ROBERT C. HIBBEN, Intern, Assoc. Ice Cream Mfgrs., Washington, D. C. Proc. 36th Ann. Conv. Intern. Assoc. Ice Cream Mfgrs. *1*, p. 19, Oct. 1936.

The work of the International Association of Ice Cream Manufacturers is herein outlined. The association attempts to serve a twofold purpose; one is the direct service it gives to the association members and the other the service rendered to the industry as a whole. During the past year one of the main activities of the association has been to work in the interests of the ice cream industry whenever Federal or State legislation affecting the industry is pending.

Another function of the association is to work with the National Bureau of Standards for simplified practices regarding ice cream cups, cartons, cans, and brick molds.

During the past year the Merchandising Bureau of the Association was changed to a separate corporate body to be known as the Ice Cream Merchandising Institute, Inc. The regular publication of the Merchandising Institute is the "Spinning Wheel." Two other publications of "Merchandising Helps" have been issued during the year. M.J.M.

133. What's Ahead for our Industry? W. R. CAMMACK, Crescent Creamery Co., St. Paul., Minn. Proc. 36th Ann. Conv. Intern. Assoc. Ice Cream Mfgrs., *1*, p. 30, Oct. 1936.

The volume of ice cream sales for the past year was the highest since 1929. Against this the cost of ingredients has increased and the tax burden has become heavier. A program of education by the industry is suggested as a means of acquainting legislative bodies as well as the public with the relation of the industry to the farmer and the consumer.

The new Revenue Laws, the Social Security Act, and other pieces of legislation make it imperative that a good system of accounting be used by all manufacturers. The Uniform System of Accounting of the International Association of Ice Cream Manufacturers meets this need. M.J.M.

134. Drought and the Dairy Outlook. H. A. Ross, The Borden Co., New York, N. Y. Proc. 36th Ann. Conv. Intern. Assoc. Ice Cream Mfgrs. *1*, p. 34, Oct. 1936.

The dairy outlook for 1932 and 1936 is compared. In 1932 practically every factor tended toward an oversupply of milk with a consequent low cost for the raw products used in ice cream mix. The number of milk cows was increasing and consumption of dairy products was decreasing. This situation brought about price cutting and distress sales.

The situation in 1936 is much improved. The cow cycle reached its peak in 1934 and has since declined about 5 per cent. For the next few years there will be a decrease in the ratio of cows to the population consuming dairy products. Employment in the manufacturing industries has risen 34 per cent since 1932. Payrolls have increased even more than re-employment. These and other indices point to a greater demand for dairy products and a higher raw products cost for ice cream manufacture. The ice cream maker can expect less competition from low priced ice cream. On the other hand, he must be alert, otherwise the cost of raw products will increase more rapidly than his selling price, thus wiping out profits.

M.J.M.

135. The Kentucky Ice Cream Tax. CARETON BALL, Hughes and Co., Lexington, Ky. Proc. 36th Ann. Conv. Intern. Assoc. Ice Cream Mfgrs. *1*, p. 52, Oct. 1936.

A tax of 28 cents per gallon was placed on ice cream by the state legislature of Kentucky in May, 1936. A comparison of ice cream sales in Ken-

tucky since the passage of the tax law with sales in neighboring states not so affected indicates a loss of approximately 50 per cent in sales of commercial ice cream. An association for repeal of the ice cream tax was incorporated in June, 1936. The association has two suits in the courts against the tax; one is so drawn that it can be carried to the United States Supreme Court if necessary.

Committee comments: This law has been repealed. M.J.M.

136. **Modern Methods in Ice Cream Making.** H. C. GUILD, Vilter Mfg. Co., New York City. Ice and Refrig. *91*, 3, p. 230, Sept. 1936.

The object of the paper is to describe that part of the ice cream industry which is of interest to the refrigerating engineer. Interesting historical information is included. A readily understandable discussion of operating difficulties in connection with direct expansion freezers is given. The advantages of stage compression are pointed out. The volumetric efficiency of compressors is clearly and simply described. L.C.T.

Other abstracts of interest are numbers 125, 131, 134, 137, 139, 140, 141, 143, 144, 145, 146, 147, 148, 149, 151, 152, 153 and 154.

MILK

137. **Maintaining the Freshness of Milk.** The Hofius Process. Milk Industry *17*, p. 45, Nov. 1936. (This article was an abstract from Deutsche Bergwerks Zeit. of Oct. 11, 1936).

The process discussed in this paper was discovered by Hofius in 1935 and deals with the preservation of milk by placing it under a pressure of ten atmospheres of oxygen. By this procedure it is claimed that milk could be kept fresh for at least five and one-half weeks.

The process consists of placing milk in stainless steel tanks admitting oxygen under ten atmospheres' pressure and shaking the container. The oxygen, together with the atmospheric air, is allowed to escape from an outlet cock; then a second charge of oxygen under a pressure of ten atmospheres is admitted and retained.

Milk that has received no pretreatment prior to the treatment with oxygen must be stored at a temperature not exceeding 8° C. in order to retain its freshness.

Professor Richter, of Kiel University, discovered that a pre-treatment of heating the milk to 58° C. for three hours would enable the milk to retain its freshness regardless of storage temperatures.

It is also stated that pre-treated and pressure treated milk retains its freshness after leaving the container for about twenty-four hours longer than will milk treated according to present day accepted practices.

In Venezuela, milk tanks filled by this process and used on ships

travelling to Africa and twice crossing the equator were found to have their milk contents unchanged after several weeks.

The process is covered by forty-one patents.

Committee Comments: There are several American patents that have been granted for the preservation of milk with oxygen. Patent (U. S.) No. 361045, dated April 12, 1887, and No. 1007046, dated Oct. 31, 1911, pertain to the use of oxygen under pressure. Patent No. 626486, dated June 6, 1899, relates to a process in which both oxygen and carbon dioxide are used under pressure.

The preservation of milk under carbon dioxide pressure is described in a Bulletin 202 of the New York Agricultural Experiment Station, 1907.

L.H.B.

138. What is Wrong with Milk Distribution? Lancet *231*, p. 1406, Dec. 12, 1936.

In a review of the Report of Reorganization Commission for Great Britain, issued by the Ministry of Agriculture and Fisheries, the Lancet points out that milk marketing boards have done excellent work but their full utility cannot yet be assessed. Producers and distributors have benefitted, but the retail cost to consumers has been raised, despite a slight increase in consumption, which has been meager in view of the efforts conducted to stimulate the use of milk.

The commission proposes that a permanent milk commission of five members be created to develop the industry, fix prices, and control any State milk subsidy, and it recommends that such a subsidy be granted to enable liquid milk prices to be relieved from their part payment of manufactured articles.

The commission's report is criticized for failure to realize how intimately the safety of milk is involved in its greater production and use, and for failure even to mention pasteurized milk. "Whatever methods are adopted for marketing milk," said the Lancet, "the position will remain unsatisfactory until a safe milk-supply is provided." J.A.T.

139. Keep Cans Clean and Sterile. M. W. Yale, Geneva, N. Y. Am. Creamery and Poultry Produ. Rev. Vol. *80*, 10, p. 317, July 10, 1935.

In the production of low count milk, it is unnecessary to resterilize milk cans at the farm if the dealer, milk hauler, and dairy farmer cooperate properly. This cooperation consists of thorough washing, steaming, and drying at the plant, prompt delivery by the hauler, and prompt removal of can covers and inversion of the cans and storage in a dry place away from dust by the farmer. By following this procedure cans will add no more than 10 bacteria per cubic centimeter to milk. Handled otherwise the count may be increased by millions. P.S.L.

140. Beet Tops and Milk Flavor. G. M. Trout and G. E. Taylor, Michigan Agr. Exp. Sta. Quarterly Bul. Vol. 18, 1, Aug. 1935.

In this study 1700 samples of milk from cows fed beet tops were examined. The flavor was affected noticeably when 25 pounds or more of beet tops were fed and in those cases where the tops were fed alone. Aeration of milk reduced the off flavor and pasteurization changed the character of the flavor. The off flavor of milk produced by feeding beet tops was especially disagreeable only in those cases where excessive quantities were fed, where the tops were of poor quality, or where frozen. It would seem, from this study, that when good feeding practices are followed, no trouble need be experienced from the normal feeding of good quality beet tops.

P.S.L.

141. Influence of Acids, Cleaners, Sterilizers, and Brines on Metals. O. F. Hunziker, Blue Valley Creamery Co., Chicago, Illinois. Am. Creamery and Poultry Prod. Rev. *80*, 15, p. 494, August 14, 1935.

The author discusses metals, plated metals, metallic alloys and metallic veneers used in dairy equipment. Glass enamels and 18–8 stainless steels are recommended. For removal of milk stone the author advises washing the utensil at 150° F. with water containing one-half of one per cent tartaric acid. Corn sugar is also a solvent of milk stone and may be so used. As dairy sterilizers only the slow-setting hypochlorites may be safely used on the usual metals used in equipment. Copper appears to be the best metal known for resistance to corrosion by brine. Tendencies toward corrosion may be reduced to a minimum by adding caustic soda until the brine becomes slightly alkaline. The addition of sodium chromate will further reduce brine corrosiveness. P.S.L.

142. Flavored Milk Drinks vs. Flavored Water Drinks. M. O. Manghan, American Dairy Foundation. Am. Creamery and Poultry Prod. Rev. Vol. *79*, 25, p. 912, April 14, 1935.

In this summary of advantages of milk drinks over other soft drinks, milk distributors are advised to sell chocolate milk in competition with the soft drinks but not in competition with whole milk; to partially defeat the milk in order to compete in price with soft drinks; and to use prepared syrups so as to insure uniformity of flavor, speed the processing, and the elimination of spoilage. P.S.L.

Other abstracts of interest are numbers 125, 126, 127, 128, 131, 134, 143, 144, 145, 146, 147, 148, 149, 151, 152, 153, and 154.

MISCELLANEOUS

143. Trends in Industrial Taxation. Ellsworth C. Alvord, Washington, D. C. 36th Ann. Conv. Intern. Assoc. Ice Cream Mfgrs. *1*, p. 40, Oct. 1936.

A thorough presentation of Federal receipts and expenditures, and re-

cent developments in taxation, is given in this paper. The author predicts higher levels for industrial taxation in the near future. M.J.M.

144. The Robinson–Patman Law. EDWIN B. GEORGE, Dun and Bradstreet, New York City. Proc. 36th Ann. Conv. Intern. Assoc. Ice Cream Mfgrs. *1*, p. 62, Oct. 1936.

The provisions of the Robinson–Patman Law and their effect on business are discussed with considerable detail in this paper. M.J.M.

145. Accomplishing Results in Employer-Employee Relations. WALTER B. WEISENBURGER. National Association of Manufacturers, New York City. Proc. 36th Ann. Conv. Intern. Assoc. Ice Cream Mfgrs. *1*, p. 83, Oct. 1936.

The National Association of Manufacturers is attempting to improve employer-employee relationships. One method now employed is a public information program by means of the press and radio. The other is to educate the employee about his relationship to the industry which he serves. M.J.M.

146. New Air Conditioned Dairy Plant at Houston, Texas. Ice and Refrig. *90*, 5, p. 349, May, 1936.

A brief description of the new $200,000.00 plant includes the dairy machinery as well as the air conditioning equipment. L.C.T.

147. Fibrous Glass For Insulation. Ice and Refrig. *90*, 5, p. 365, May, 1936.

The Corning Glass Company after eleven years of research has been able to manufacturer a well felted flexible mass resembling cotton but possessing the chemical stability characteristics of glass. The fibres have a diameter ranging from 1/7 to 1/50 of that of human hair. The thermal coefficient ranges from 0.266 B.T.U. per sq. ft. per degree F. per hour per inch of thickness at 70° F. mean temperature and 1½ lbs. per cubic foot, to about 0.60 B.T.U. at the higher temperatures for which the material is recommended and 6 pounds per cubic foot density. The material is acid proof (except for hydrofluorie), vermin proof, weather proof, and will withstand temperatures up to 1000° F. L.C.T.

148. Air Cleaning Equipment and its Operation. H. C. MURPHY, Am. Air Filter Co., Louisville, Ky. Ice and Refrig. *91*, 1, p. 67, July, 1936.

This is an interesting résumé of investigations on air pollution and its influence on health. Data are included giving the kind and amount of dust in the air of various cities. Specifications are included for satisfactory air filters and their use, as well as brief descriptions of various types of equipment. L.T.C.

149. Methods and Systems of Defrosting. Ice and Refrig. *91*, 2, p. 25, Aug., 1936.

Ice and Refrigeration carries only a brief review of a paper presented by Siegfried Ruppricht, consulting engineer of N. Y. city, at the spring meeting of the A. S. R. E. In the original paper, twenty different methods of defrosting and nine different methods of controlling them were described. Some are listed below:—

1. Picking and scraping.
2. Increasing pressure in the evaporator and releasing it suddenly.
3. Spreading brine over frost, and washing away.
4. Pouring water over thickly frosted coils.
5. Use of electric heaters.
6. Shutting circulation off the frosted coil.
7. Reversing the cycle.

L.C.T.

150. Securing Carbon Dioxide with Converters. Roy E. McIlrath, Stanley Knight Corp. Ice and Refrig. *91*, 5, p. 355, Nov., 1936.

An interesting side line to dry ice is the use of converters for securing a cheap, pure carbon dioxide gas for any purpose. The price of dry ice has steadily declined during recent years because the production of this commodity has increased from 340,000 lbs. per year in 1925 to 230,000,000 lbs. in 1935, and because its production has become a by-product of many plants. Whereas dry ice can be purchased at 3 cents per lb. in 50 lb. lots, liquid carbon dioxide is selling for 6 cents per lb. The difference in cost is largely due to handling charges and overhead.

L.C.T.

151. An Analysis of Absorption Systems. A. B. Stickney. Ice and Refrig. *90*, 5, p. 322, May, 1936, *90*, 6, P. 395, June, 1936, *91*, 1, p. 3, July, 1936, *91*, 2, p. 93, Aug., 1936.

The first of the series of four articles includes a chart giving the thermal properties of ammonia-water solutions. The chart is the result of conversion into English units from data reported by German investigators.

The second article includes a diagram of a simple absorption system as well as tables showing conditions existing at each point of the cycle. A detailed discussion of the thermodynamics of the system is included.

The third article continues the discussion begun in the second, covering combinations of auxiliary, and a derivation of complete heat balance as a guide to method of analysis.

The last article includes a discussion of the advantages of the compound cycle.

L.C.T.

152. The Cold Storage Locker Business. Ward E. Guest. Ice and Refrig. *91*, 4, p. 280, Oct., 1936.

During the past five years approximately 1500 cold storage locker plants have been put into use. To give adequate service to its patrons, a plant must have an adequate chill room with full butchering equipment, a sharp

freeze room with a temperature of – 10° F. It should also be equipped for curing meat. This room should be kept between 36° and 38° F. Lockers should be provided with built in locks and should also be removable for cleaning. Entrance to lockers should be so arranged that the attendant may see everyone who comes and goes, so that no unfrozen products are placed in the lockers. The cutting room may well serve as an ante-room to the lockers. Cold storage plants may be operated in connection with local dairies. L.C.T.

153. New Diesel Power Unit Reduces Operating Costs. Ice and Refrig. *91,* 5, p. 401, Nov., 1936.

A brief description is given of a 4 cylinder 77 hp. caterpillar Diesel unit in a combined creamery and ice plant at Pittsfield, Ill. A table of operating costs indicates that on a limited output of 9 tons ice per 24 hours with purchased power, the cost per ton of ice was $2.74, whereas in the present setup with capacity of 14.4 tons per 24 hours the cost per ton of ice is $.85 due to lesser power fluctuation. Additional savings result from the use of the Diesel engine for generating power for the dairy plant. L.C.T.

154. Carbon Dioxide in Its New Field of Usefulness. J. C. Grossman. Ice and Refrig. *90,* 2, p. 147, Feb., 1936, *90,* 3, p. 219, Mar., 1936, *90,* 4, p. 289, Agr., 1936, *90,* 5, p. 359, May, 1936, *91,* 1, p. 58, July, 1936, *91,* 2, p. 137, Aug., 1936, *91,* 3, p. 218, Sept., 1936, *91,* 4, p. 304, Oct., 1936, *91,* 5, p. 304, Nov., 1936.

This is a continuation of a series of articles, publication of which was temporarily suspended in July, 1931. Developments since that date are covered. A great mass of historical information as well as patent data are included. A description is given of absorbers and compressors as well as diagrams of installation together with technical data on operation. The thermodynamics of carbon dioxide as used in refrigerating equipment is discussed. Economies of CO_2 refrigeration are pointed out. Line drawings for quantity production of low temperature liquid CO_2 are given. The terms enthalpy and enthropy are discussed. Absorbers and absorbents in production of CO_2 are described and evaluated. L.C.T.

155. The Karlsruhe Cryogenic Institute. J. S. Gooseman. Ice and Refrig. *91,* 5, p. 394, Nov., 1936.

The report reviews the work of the above Institute for the past ten years, and points out that its activities are divided into:—

1. Physiological, chemical research.
2. Refrigerating machinery and equipment.
3. Application of low temperature.
4. Problems of the refrigerating industry.

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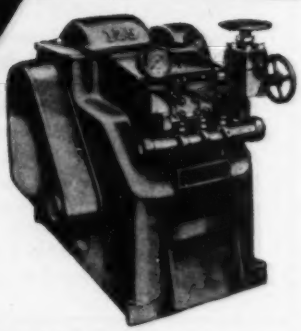

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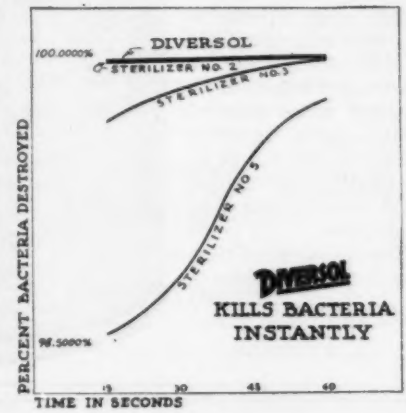

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DETROIT, MICHIGAN